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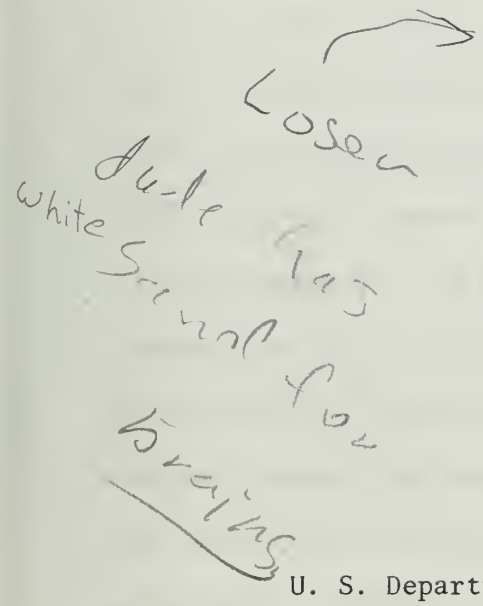

FINAL REPORT

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Measurements of the Light-reflecting Properties of White Gypsum Sand

Abstract

A series of laboratory measurements was carried out for determining in detail the reflection characteristics of white gypsum sand. This information is necessary for the utilization of the White Sands area of New Mexico as a calibration target for a satellite radiometer while in orbit. The data obtained consists of the directional reflectance of the material and the degree of polarization of the reflected light, as functions of angle of incidence, angle of view, and wavelength of the radiation for two different moisture conditions of the white gypsum sand.

I Background

In a recent study (Coulson and Jacobowitz - 1972), it was determined that a reasonably good calibration for the visible channel of an orbiting satellite radiometer can be obtained by making use of the area of the White Sands National Monument of New Mexico as a calibration target to be viewed by the instrument. In order to utilize the method, it is necessary to measure the optical thickness of the atmosphere, the radiant flux incident at the surface, and the directional reflectance of the surface itself. The National Oceanic and Atmospheric Administration has developed instrumentation for determining the first two of these quantities; this report presents measurements of the third.

II Theory of measurements

A radiation field in an arbitrary state of polarization can be represented in terms of four quantities, which are usually called the Stokes

parameters after the English physicist of the 19th century Sir George Stokes. If we denote two orthogonal directions in the plane normal to the direction of propagation of the radiation by i and j, then the intensities I_i and I_j are, respectively, the squares of the amplitudes of the electric vector along the i and j directions. The total intensity of the radiation, which is the first of the Stokes parameters, is given by

$$I = I_i + I_j \tag{1}$$

The other three of the Stokes parameters are defined in terms of the orthogonal components as follows:

$$\begin{aligned} Q &= I_i - I_j \\ U &= 2\,(I_i I_j)^{1/2} \cos\delta \\ V &= 2\,(I_i I_j)^{1/2} \sin\delta \end{aligned} \tag{2}$$

δ is the phase angle between the vibrations in the i and j directions. If χ is the angle between the direction i and the major axis of the ellipse described by the vibration of the electric vector of the radiation, then

$$U = Q \tan 2\chi \tag{3}$$

The parameter V is expressed in terms of the major and minor axes of the ellipse, denoted by a and b respectively, by the relations

$$\begin{aligned} V &= I \sin 2\beta \\ \beta &= \arctan\left(\frac{b}{a}\right) \end{aligned} \tag{4}$$

The degree of polarization is

$$P = \frac{(Q^2 + U^2 + V^2)^{1/2}}{I} \tag{5}$$

In the present measurements it is assumed that the only type of polarization present is linear, in which case

$$V = 0 \tag{6}$$

Then the only quantities necessary to characterize this partially linearly polarized radiation are I_i, I_j, and χ.

Directional reflectance of the surface is obtained in the following manner. It is known that a surface composed of magnesium oxide or photometric sphere paint (Kodak) represents, to a good approximation, a perfectly diffuse surface with a reflectance of 1.0 for visible light. Such a surface is used as a standard reflector. If F units of energy per unit time and unit frequency interval are incident on a unit area of the standard surface, the intensity I_s of energy reflected into an incremental solid angle $d\omega$ is independent of direction and satisfies the relation

$$\int_\Omega I \mu \, d\omega = R_s F = F, \tag{8}$$

where $\mu = \cos \theta$, θ being the nadir angle at which the surface is viewed. R_s represents the total reflectance of the standard surface, which is taken as unity, and the integration is taken over the entire hemisphere. The directional reflectance ρ_s for the standard surface is defined by the relation

$$\rho_s = \frac{I_s}{F} \tag{9}$$

Obviously ρ_s is a constant for a perfect standard (Lambert) surface. By Eq. (8) and Eq. (9), integration over a hemisphere yields, for the standard surface,

$$\int_\Omega \rho_s \mu \, d\omega = R_s = 1 \tag{10}$$

and

$$\rho_s = \frac{1}{\pi} \tag{11}$$

Let $I(\mu,\phi)$ denote the intensity of radiation reflected from a sample surface into a direction given by the nadir angle θ and azimuth ϕ for the condition in which the sample is likewise illuminated by F units of energy

per unit time and unit frequency interval. We can now define a direction-dependent reflection coefficient $\rho(\mu,\phi)$ for the surface by the relation

$$I(\mu,\phi) = \rho(\mu,\phi) F. \tag{12}$$

These quantities must satisfy the relations

$$\int_\Omega I(\mu,\phi)\, \mu\, d\omega = RF \tag{13}$$

$$\int_\Omega \rho(\mu,\phi)\, \mu\, d\omega = R,$$

where R is the ratio of the total reflected energy to the total incident energy.

The procedure followed for the actual measurements is to illuminate the standard surface in a direction given by the zenith angle $\theta_o \equiv \arccos \mu_o$ and azimuth angle $\phi_o = 0$ and set the instrument to view the standard surface from a direction (θ,ϕ). If the standard were a perfect Lambert surface, the measured intensity would be independent of θ and ϕ. However, in order to assure uniformity in the measurements, the standard surface is always viewed from the direction of the surface-normal, in which case $\theta = 0$ and ϕ is indeterminate. Thus, an instrument response D_s for the standard surface is obtained. The intensity I_s of the reflected light is then

$$I_s = \Delta_s D_s, \tag{15}$$

where Δ_s is the instrument transfer function at intensity I_s.

The standard surface is then replaced by the sample for which the reflection characteristics are desired. The sample is viewed from any desired direction, given by (θ,ϕ), and a second instrument response $D(\theta,\phi)$ is obtained. The intensity $I(\theta,\phi)$ is

$$I(\theta,\phi) = \Delta D(\theta,\phi) \tag{16}$$

where Δ is the instrument transfer function at this new intensity.

The instrument transfer function may or may not be independent of

intensity, the only requirement being that it be a known function. The most convenient situation is that Δ is a constant over the range of intensities of interest, or $\Delta_s = \Delta$. This ideal situation is achieved in the present instrument, as photon counting and digital transfer techniques are used throughout the system.

On taking the ratio of Eq. (16) to Eq. (15) and introducing Eq. (9) and Eq. (12) we obtain

$$\frac{I\ (\theta,\phi)}{I_s\ (0,\ -)} = \frac{D\ (\theta,\phi)}{D_s(0,-)} = \frac{\rho\ (\theta,\phi)}{\rho_s(0,-)} \tag{17}$$

The assumption has been made that the incident flux F is constant.

Finally, by introducing the known value of ρ_s given by Eq. (11), we obtain the final expression for the directional reflectance of the sample surface in the (θ,ϕ) direction as

$$\rho(\theta,\phi) = \frac{1}{\pi} \quad \frac{D\ (\theta,\phi)}{D_s(0,-)} \tag{18}$$

III Measurements

The directional reflectance and degree of polarization of the reflected light were measured for the following sets of parameters for the sand in a dry state:

Wavelength	Angle of Incidence	Nadir Angle of View	Azimuth Angle of View
0.40 μm	0°	0°	0°
0.50	10	10	30
0.60	20	20	60
0.70	30	30	90
0.80	40	40	120
0.90	50	50	150
	60	60	180

Visual inspection of the White Sands area shows that the reflectance of wet gypsum sand is somewhat lower than that of the sand in the dry state. This difference is of considerable importance for the calibration problem, as a very high water table keeps the very low parts of the White Sands area in a permanently wet condition. Thus the average reflectance is decreased by an amount proportional to the extent of the wet sand area. With a knowledge of the reflection characteristics of the sand in a state of wetness, appropriate corrections to the data can be made.

In order to obtain the required data, the number of measurements were made on wet sand, the parameters for the measurements being the following:

Wavelength	Angle of Incidence	Nadir Angle of View	Azimuth Angle of View
0.40 μm	0°	0°	0°
0.50	20	20	30
0.60	40	40	60
0.70	60	60	90
0.80		70	120
0.90			150
			180

The data are presented in tabular form at the end of this report.

IV Experimental Details

A high precision computer-controlled dual-channel polarizing radiometer[1] was used in conjunction with a newly constructed computer-controlled scattering table for the present measurements. The system was programmed to collect all the data for a given wavelength and source angle θ_o automatically. The

[1] Kinsell L. Coulson and Robert L. Walraven - A high-precision computer-controlled dual-channel polarizing radiometer, Bulletin of the American Meteorological Society, Vol. 53, No. 5, May 1972, p. 509.

raw data were reduced to the final results in two steps, so that the entire available data (of which the final results are just a part) could be examined and errors corrected before the final printout.

A. The Polarizing Radiometer

A schematic diagram of one channel of the polarizing radiometer is shown in Figure 1. The incoming light signal, after being collimated, passes through a shutter which can be closed for dark count readings. A quarter-wave plate (which was not used for these measurements) is located behind the shutter and can be inserted for measurements of the circular component of polarization for applications where this is necessary. The light beam then passes through a Glan/Thompson polarizing prism which can be rotated in 5° steps. The intensity of the beam can then be adjusted by a set of four neutral density filters which allow an attenuation by a factor of up to 30,000 when all four filters are inserted simultaneously. Next the beam passes through one of three .01μ- wide interference filters. One channel of the instrument contains interference filters for which peak transmissions are at .4, .5, and .6μ, and the other contains interference filters at .7, .8, and .9μ. Finally, the beam impinges on a photomultiplier tube. An EMI 6256A tube is used for the shorter wavelengths and an EMI 9659A tube with focusing magnets to reduce the dark count is used for the longer wavelengths.

Light is quantized by nature, and the photomultipliers are capable of producing an electronic pulse for each quantum of light. These pulses are approximately one nanosecond in duration. By means of a suitable high-gain wide-band amplifier and a pulse-height discriminator, each of these pulses is converted into a standard 10 nanosecond long logic pulse compatable with digital logic. The intensity of light on the photomultiplier is easily

determined by simply measuring the resulting pulse rate. This pulse rate, after being corrected for photomultiplier dark count and discriminator dead-time, is linearly proportional to the light level incident on the photo-multiplier.

All mechanical motion within the instrument is controlled automatically by a PDP-11 minicomputer. An interactive software program allows the instrument to be controlled in the immediate mode by simple commands, or in the deferred-mode where a program of complex instrument operations can be performed. The raw data from the instrument are stored on magnetic tape, and can be played back and reduced immediately after a data run.

B. The Scattering Table

The polarizing radiometer is mounted on a scattering table that can be controlled automatically by the computer. This allows an entire scan of the sample to be programmed. The geometry of the scattering table is shown in Figure 2. An automatic sample changer allows either the white sand sample or the standard surface to be inserted on the stage of the scattering table. The polarizing radiometer is mounted on an arm which pivots about the center of the table and allows the instrument to be set to any nadir angle θ between -90° and 90°. The source is a 650 watt General Electric Quartzline lamp which has a color temperature of 3400°K. The azimuth ϕ_o and elevation θ_o of the source can both be set to within 0.1° of any angle in the upper hemisphere shown in Figure 2.

Since the detector could not be moved in the azimuthal direction, the azimuthal dependence required for this report was obtained by varying the azimuthal direction of the source rather than the detector. It is assumed that a measurement of the reflectance with the source at an azimuthal angle ϕ_o and the detector at 0° is identical to a measurement with the source at

0° and the detector at $\phi = \phi_o$. This assumption is reasonable since white gypsum sand, except for small order local variations, has no features which could yield a left-right asymmetry or a change in reflectance as the sample is rotated.

The scattering table, polarizing radiometer, and PDP-11 computer are shown in Figures 3a and 3b.

C. Analysis of Data

It can be shown that the intensity of light on the photomultipler should be

$$I = I_o [1 + P \cos 2 (\chi + \psi_1)] \tag{19}$$

where I_o is the first Stokes parameter (total intensity), P is the degree of polarization, and ψ_1 is the angle of rotation of the Glan-Thompson prism. I_o and P were determined by taking eight measurements with the Glan-Thompson prism rotated 45° between each measurement, and fitting the data in the least-squares sense. In practice, the form

$$I = I_o [1 + A \cos (\chi + \psi_o) + P \cos 2 (\chi + \psi_1) + B (\chi - \psi_{avg})/180] \tag{20}$$

gave a better fit to the data than equation (19). Chi-squared per degree of freedom using equation (2) was typically $\sim$1, which indicates that the data contain no significant information which is not described by equation (2). The parameters A and ψ_o arise from angular-dependent internal reflections within the instrument and the parameter B arises from any linear drift in the source intensity during the measurements. ψ_{avg} is the average of the eight values of the angle of rotation of the Glan-Thompson prism, ψ.

Data were accumulated on separate runs for each wavelength and source angle θ_o. After initial reduction and analysis, the reduced data for each run were printed out for visual inspection. Typical results are shown in

Table 1. The values of I_o and P were used for the final tabulation.

Table 1. Initial printout of reduced data for $\lambda = .6\mu$, $\theta_o = 60°$, $\phi = 0°$.

θ	I_o	B	A	ψ_o	P	ψ_1
70	1.058	-.002	.005	187	.098	195
60	.931	-.001	.004	196	.065	194
50	.863	.002	.004	177	.052	194
40	.819	.003	.004	158	.043	194
30	.783	-.008	.005	195	.034	198
20	.758	.001	.004	168	.024	196
10	.740	.001	.004	157	.019	195
0	.728	.002	.004	159	.014	194

D. Wet Sand Preparation

A 1/4-inch deep metal tray sprayed with flat white Krylon paint was used to hold the wet sand. A shallow tray was used so that the water level could be kept near the surface of the sand. A 1/4-inch layer of sand was was more than sufficient to prevent the bottom of the tray from being visible, even when the sand was saturated.

The water level in the tray could not be controlled very accurately. An attempt was made to keep the level fairly constant by adding water to the sample periodically, but the light-reflecting properties of the sand changed visibly during the period of a single data run. This change is responsible for some irregularities in the curves applicable to wet sand.

V Discussion of Data

The final reduced data on dry and wet sand are given in tabular form at the end of this report. The values given for directional reflectance are

$$\pi\rho(\theta,\phi) = \frac{D\ (\theta,\phi)}{D_S\ (o,-)} \quad .$$

Selected data are also given in graphical form in Figures 4 through 16, and the results of some additional measurements are presented in Figures 17 and 18.

In the following discussion, two different types of reflection will be mentioned. One is diffuse reflection, wherein the intensity of the reflected radiation is uniform in all directions, and the second is specular reflection, wherein all the reflected radiation occurs at an angle of view equal to the angle of incidence. In practice, all real surfaces fall somewhere between these two ideal limiting cases.

A. Case of Dry Sand

The directional reflectance of dry white gypsum sand is shown in Figures 4, 5, and 6 for an angle of incidence θ_o of 0°, 30°, and 60° respectively. The directional reflectance at wavelengths of .6, .7, .8 and .9μ is similar in all three figures, while the directional reflectances at .5μ and .4μ are progressively lower, but with the same general angular dependence. The angular dependence of the data is consistent with the findings of Torrance and Sparrow[2], who predict that for any surface that is somewhere between a diffuse and a specular reflector

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[2] K.E. Torrance and E.M. Sparrow "Theory for Off-Specular Reflection from Rough Surfaces", Journal of the Optical Society of America 57 No. 9, pp 1105-1114 (1967) and "Off-Specular Peaks in the Directional Distribution of Reflected Thermal Radiation", Journal of Heat Transfer 88 Series C, pp 223-230 (1966).

1. A diffuse distribution is approached with increased surface roughness (or shorter wavelength) only when the incident flux arrives in a near-normal direction.
2. At moderate and large angles of incidence a maximum in the distribution of reflected radiance occurs at an angle of view larger than the specular angle $\theta = \theta_o$.
3. The magnitude and sharpness of the off-specular peak increase with increasing angle of incidence.

The hemispheric dependence of the directional reflectance of dry white gypsum sand at an angle of incidence of 30° and a wavelength of .6μ is shown in a polar plot of $\pi\rho(\theta,\phi)$.

The principle of reciprocity states that for a small spot on the sample surface the directional reflectance should not change if the angle of incidence and angle of view are interchanged. Figure 8 shows the directional reflectance for an angle of view of 0°, as a function of the angle of incidence. These results should be compared with those shown in Figure 4, where the role of the angle of incidence and angle of view are interchanged. The difference of these two results seems to conflict with the principle of reciprocity. This apparent paradox can be resolved when we consider the roughness of the surface. If the angle of view and angle of incidence are exchanged, the actual part of the surface in view changes, due to shadowing and hiding of low surface features by higher surface features. Since the principle of reciprocity applies only if the surface viewed is identical for the two cases, there is no reason to expect it to hold in the case of a rough surface.

The directional reflectance of dry white gypsum sand as a function of wavelength is shown in Figure 9 for an angle of view of 30°. The sharp

drop in directional reflectance below .6μ is consistent with the finding of Bennett[3] for various kinds of ground glass. He found a sharp decrease to zero reflectance at zero wavelength for wavelengths below the average particle size. This would indicate that the grains of the white gypsum sand have surface structure of dimensions on the order of .6μ. Inspection of individual grains indicates this conclusion is reasonable. The small fluctuations in the directional reflectance at wavelengths above .6 are not understood, but they may be due to an absorption band in this wavelength region, but the point needs further confirmation.

The degree of polarization given in the tables has not been corrected for a small contribution to the measured polarization due to effects in the polarizing radiometer. Although the contribution from the instrument should be subtracted vectorially from the measured results, subtracting the proper scalar quantity introduces only a small error unless the actual degree of polarization is less than one percent. The correction, Δ, which should be subtracted from the tabulated values for degree of polarization and the maximum error, ε, (which occurs for zero polarization) caused by making a scalar rather than a vector correction is as follows:

WAVELENGTH	Δ	ε
.4μ	0	.003
.5	.002	.005
.6	.001	.001
.7	-.006	.006
.8	-.005	.006
.9	.027	.002

[3]H.E. Bennett "Specular Reflectance of Alumimized Ground Glass and the Height Distribution of Surface Irregularities", Journal of the Optical Society of America 53, No. 12, pp 1389-1394 (1963).

The degree of polarization of dry white gypsum sand for an angle of incidence of 0°, 30°, and 60° is shown in Figures 10, 11, and 12, respectively. The instrumental correction for these data was made vectorially. The degree of polarization has relatively little wavelength dependence in the 0.6 - 0.9μ region, whereas there is a progressive increase of P with decreasing wavelength below 0.6μ. It is notable also that the degree of polarization shows the same off-specular peak, that increases with angle of incidence, as does the directional reflectance. This information, when compared with the directional reflectance data in Figures 4, 5, 6, and 9, indicates that the degree of polarization arises from the same mechanism as the directional reflectance. The neutral points, where the polarization changes sign, can be seen in Figures 11 and 12. The well-defined neutral point in Figure 12 shows no apparent wavelength dependence; data point scatter makes the neutral point positions somewhat uncertain in Figure 11.

B. Case of Wet Sand

The directional reflectance of wet white gypsum sand for an angle of incidence of 0°, 40°, and 60° is shown in Figures 13, 14, and 15, respectively, and the degree of polarization for an angle of incidence of 60° is shown in Figure 16. The dependence of the data on angle of view for an angle of incidence of 0° (Figure 13) is not greatly different from that for dry sand (Figure 4), except that the overall magnitude of the directional reflectance is lower. Any specular behavior in these data, however, would not be apparent, because the specular peak would occur at an angle of view of 0° where the source blocks the view of the detector. On the other hand, the data for an angle of incidence of 40° and 60° show definite evidence of a specular component. Although the specular contribution is not entirely apparent at an angle of incidence of 40° at .4 and .5μ, it is obviously

apparent for an angle of incidence of 60°. The data at .8μ have a very strong specular component, with the peak in directional reflectance near the specular angle. The data in Figure 14 show that at wavelengths where the specular component is smaller, the peak in the directional reflectance shifts to larger angles of view. The amount of specular component as a function of wavelength has no meaning here, since, as mentioned above, the water content of the sand could not be controlled consistently from run to run.

The degree of polarization of wet white gypsum sand for an angle of incidence of 60° (Figure 16) also shows a large component due to specular contributions. The positions of the neutral points, where the polarization changes sign, are poorly defined compared to those for dry sand.

In order to better understand the directional reflectance of white gypsum sand in a wet state, an additional experiment was performed. The sand was first fully saturated with water so that the water could be seen standing on the surface. The directional reflectance and degree of polarization at .6μ for an angle of incidence of 60° was then measured as a function of time as the sand dried. The results are shown in Figures 17 and 18 for an angle of view of 0° and 60°. The peak of the specular component should occur at an angle of 60°. The data show a strong specular component, which decays to zero in 2 to 3 hours, and a non-specular component, which slowly increases with a time constant of 10-15 hours. The results are explained as follows. When water is standing on the sand, a strong specular component results, due to reflection from the water surface. This specular component drops off rapidly as the water level drops below the surface. Since the sand is still damp, the index of refraction of the grains is lowered and the grams transmit more light to lower layers than for the case of dry sand. Thus, while the angular dependence for damp

(but not saturated) sand may be similar to the angular dependence for dry sand, the overall intensity is lower, due to more absorption into the sand when it is wet.

VI Conclusion

In conclusion, dry white gypsum sand seems to be a suitable calibration target for a satellite radiometer while in orbit as long as either the angle of incidence or angle of view is kept small. The decrease in reflectance due to wet spots in the White Sands area can be estimated, provided water is not standing on the surface and specular angles are avoided.

VII Organization of the Data Tabulation

The data tabulation consists of 67 pages, the first section (43 pages) being for dry sand and the second section (24 pages) for wet sand. Each of the two sections is divided into six parts, one for each of the six wavelengths for which measurements were made (0.4, 0.5, 0.6, 0.7, 0.8, 0.9μ). The sheets for each wavelength are arranged according to angle of incidence, the angles being θ_o = 0, 10, 20, 30, 40, 50, 60° for measurements on dry sand and θ_o = 0, 20, 40, 60° for those on wet sand. An extra page is given for θ_o = 80°, λ = 0.7μ. Finally, each page is divided into a tabulation for directional reflectance and a tabulation for degree of polarization. The parameter THETA in the tabulations is nadir angle of view of the radiometer, and PHI is azimuth angle of the radiometer. The sense of the azimuth is that the instrument received specularly reflected radiation when it was at an azimuth of 0°.

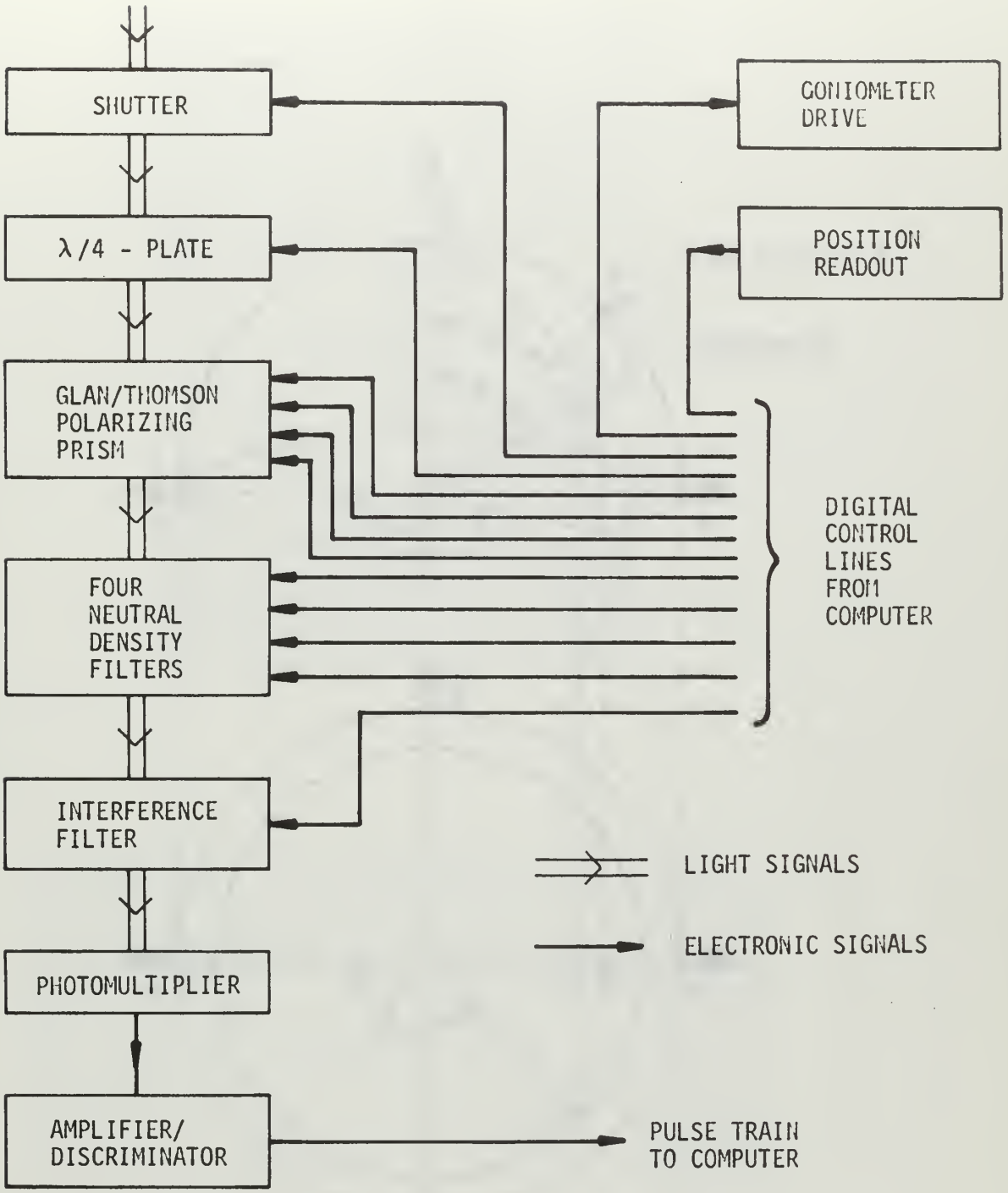


FIG. 1 SCHEMATIC DIAGRAM OF ONE CHANNEL OF THE POLARIZING RADIOMETER

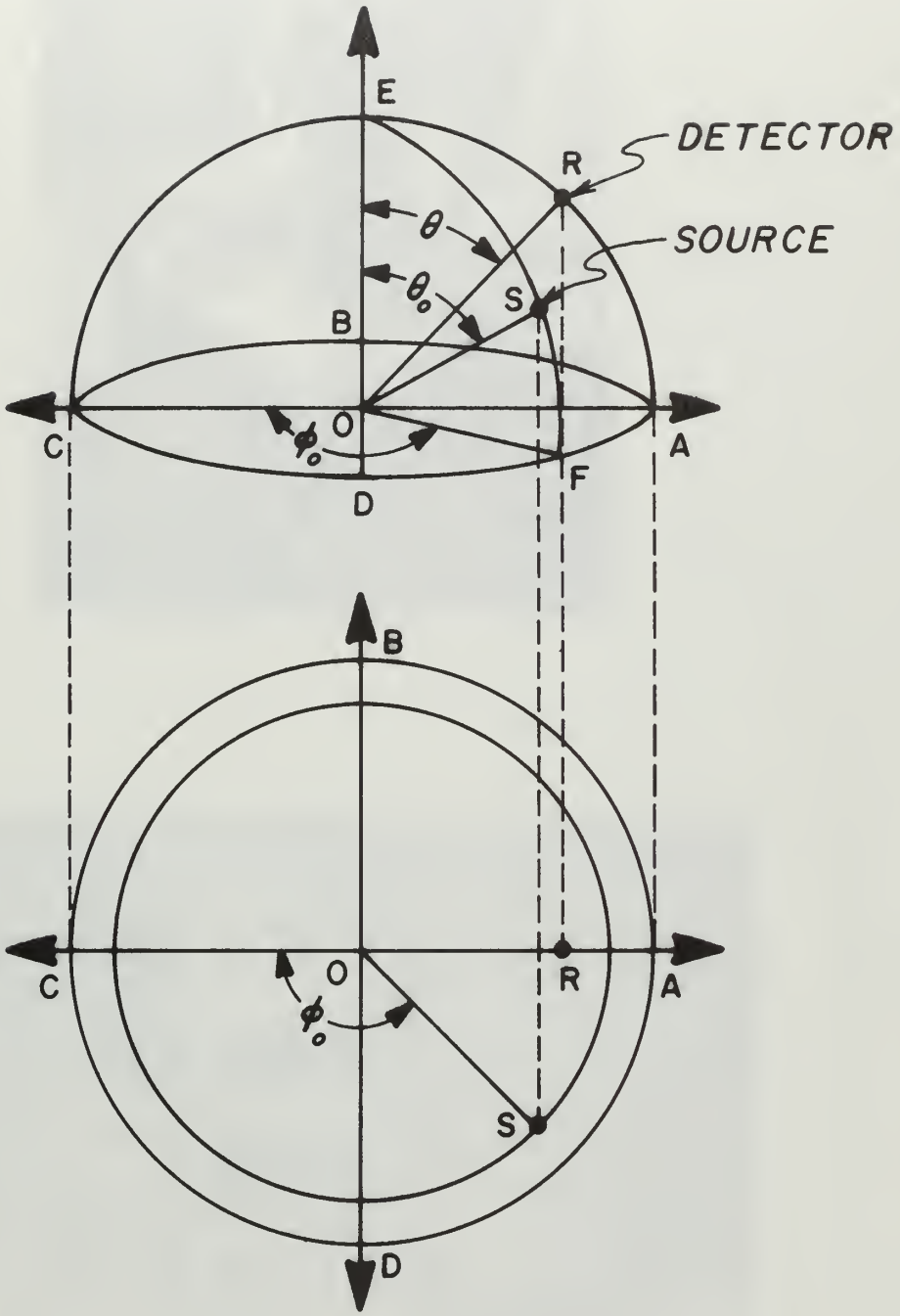
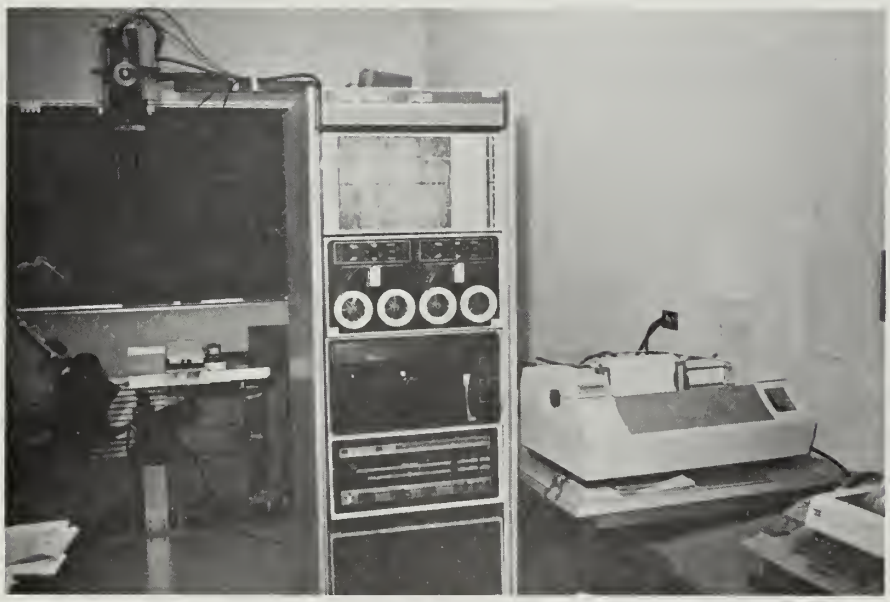


FIG. 2. EXPERIMENTAL GEOMETRY

a)



b)

FIGURE 3. a) THE SCATTERING TABLE WITH POLARIZING RADIOMETER, b) THE PDP-11 COMPUTER WITH SCATTERING TABLE IN BACKGROUND.

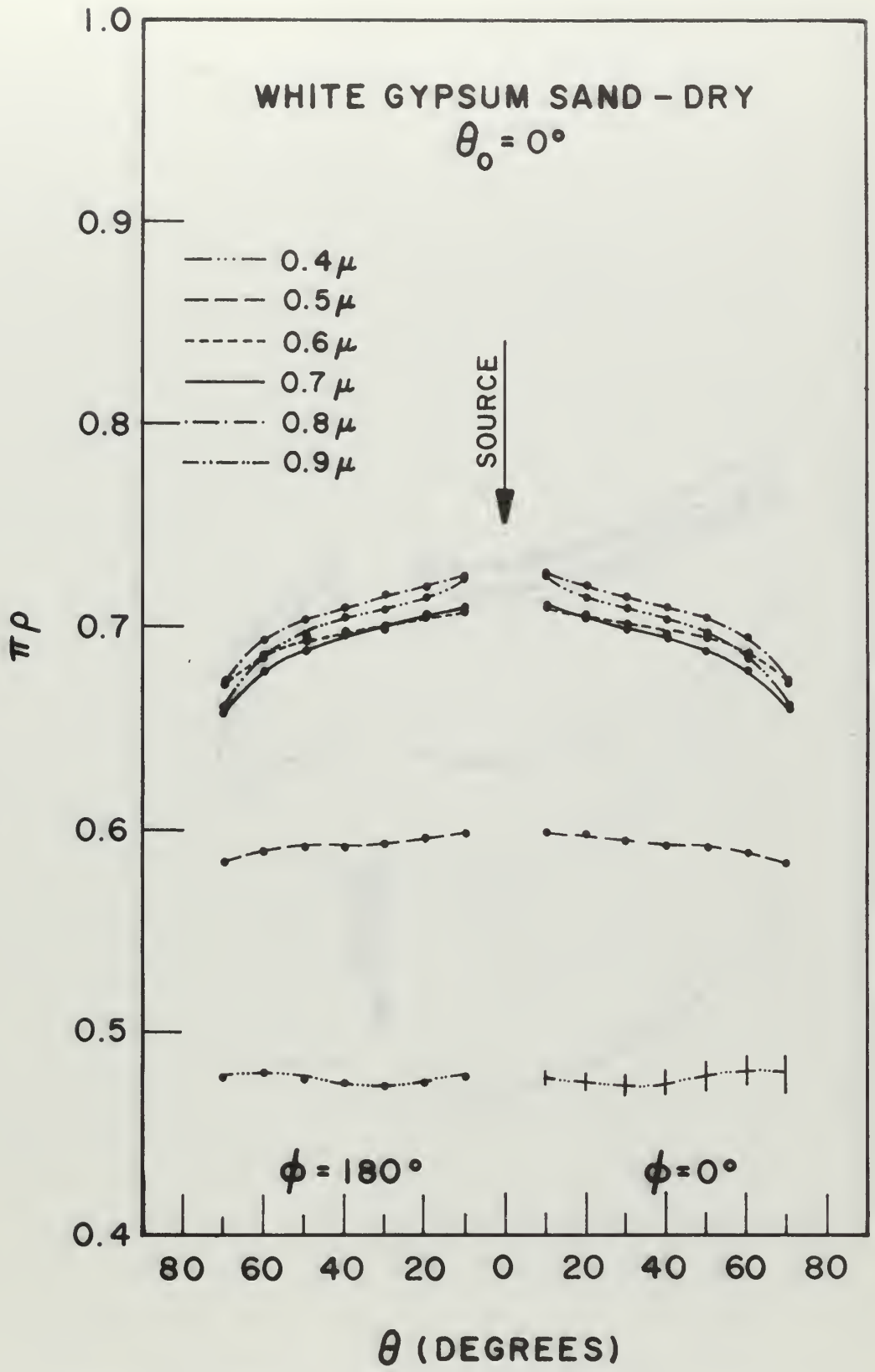


FIG. 4 REFLECTANCE OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 0 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

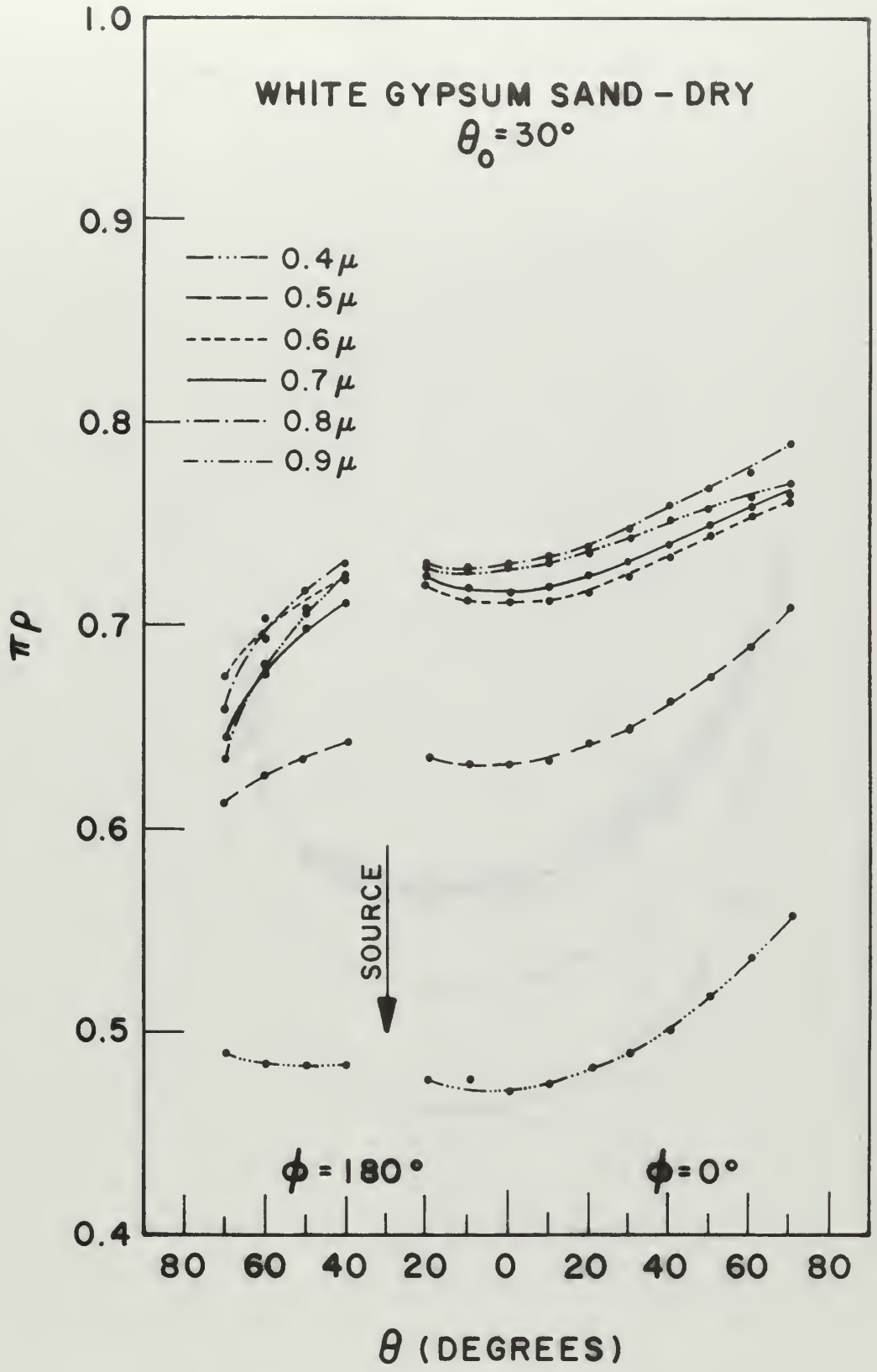


FIG. 5 REFLECTANCE OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 30 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

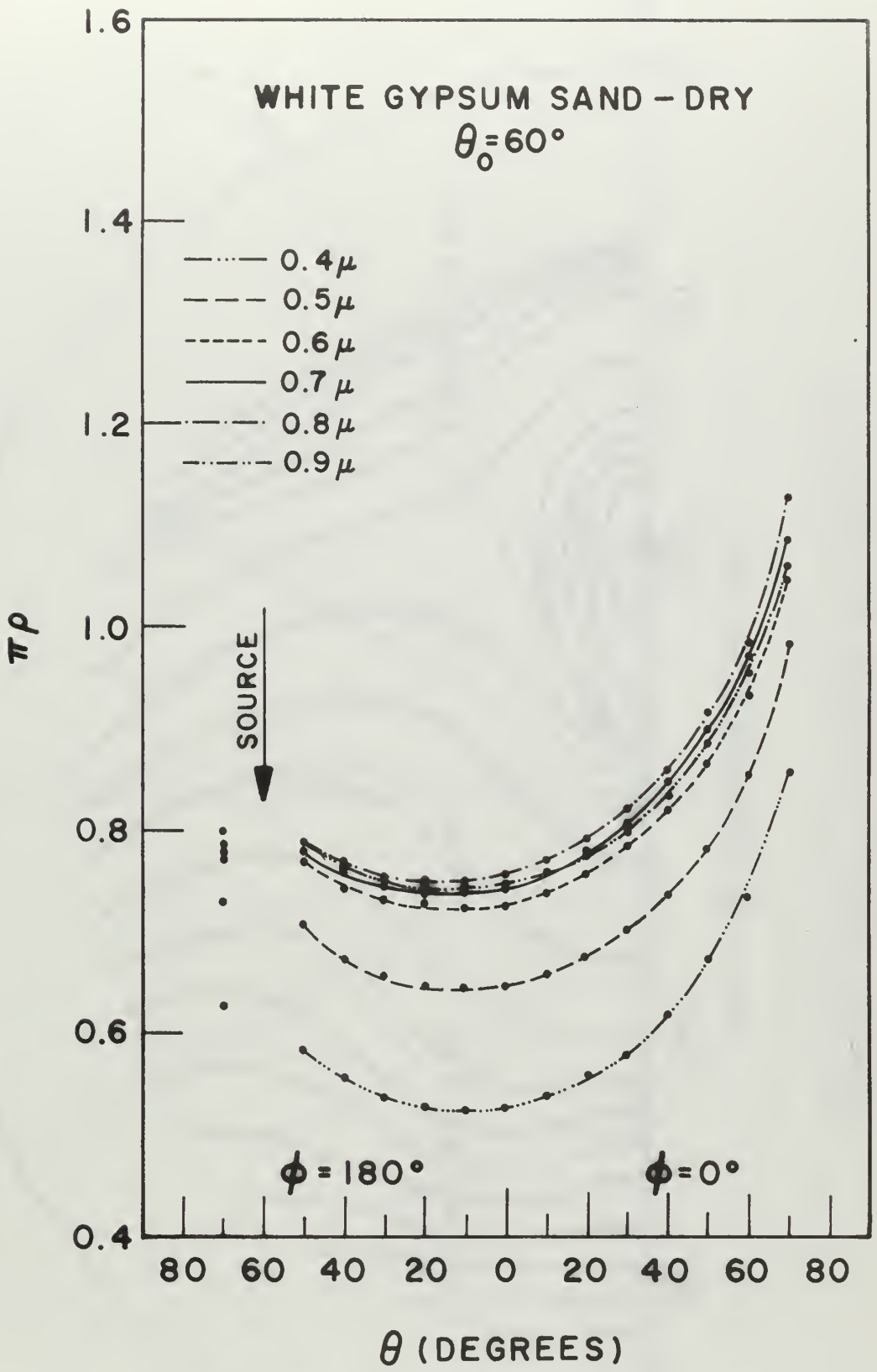


FIG. 6 REFLECTANCE OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 60 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

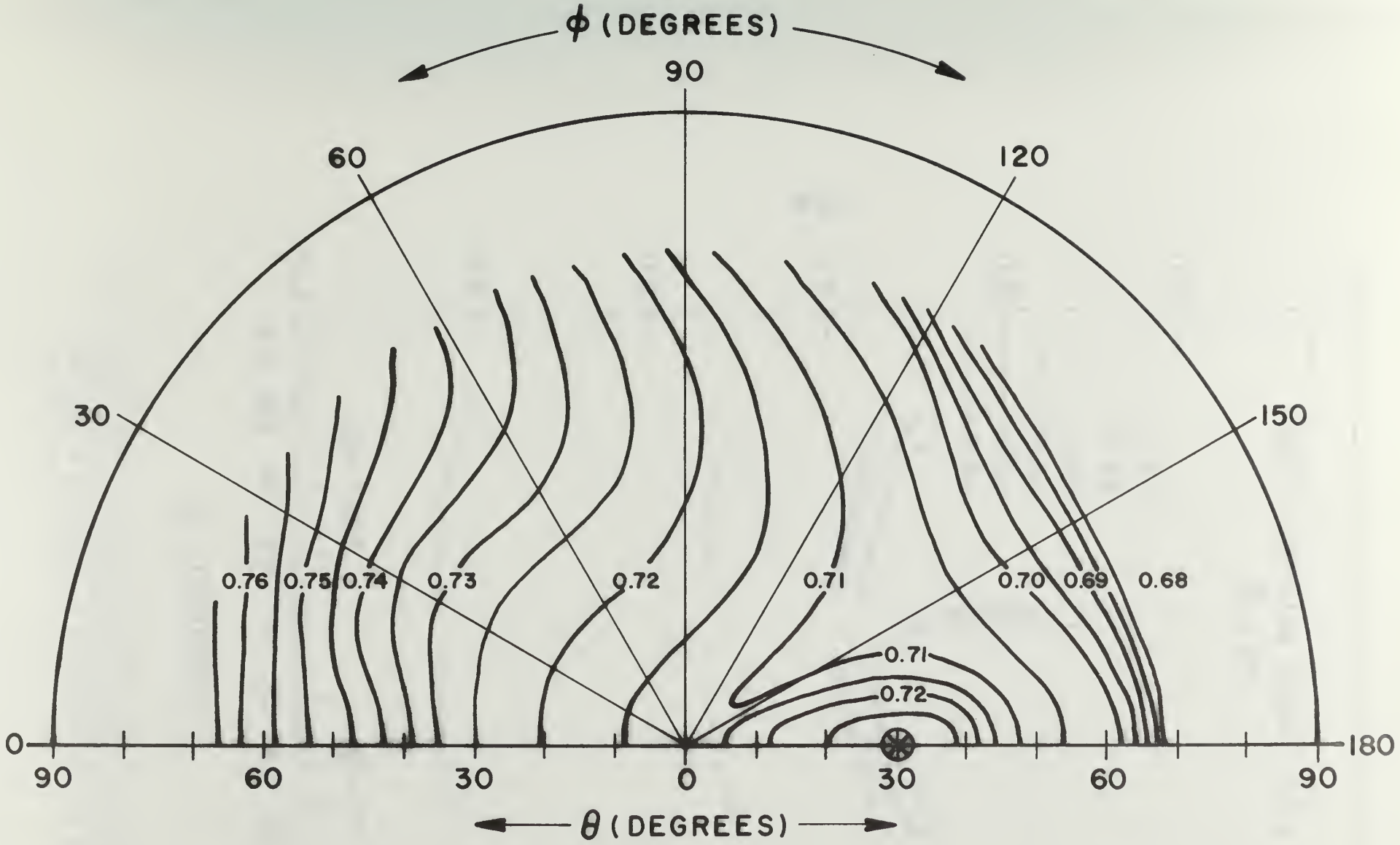


FIG. 7 POLAR PLOT OF REFLECTANCE OF DRY WHITE GYPSUM SAND FOR AN ANGLE OF INCIDENCE OF 30 DEGREES AT A WAVELENGTH OF 6 MICRONS. (⊗ IS THE POSITION OF THE SOURCE)

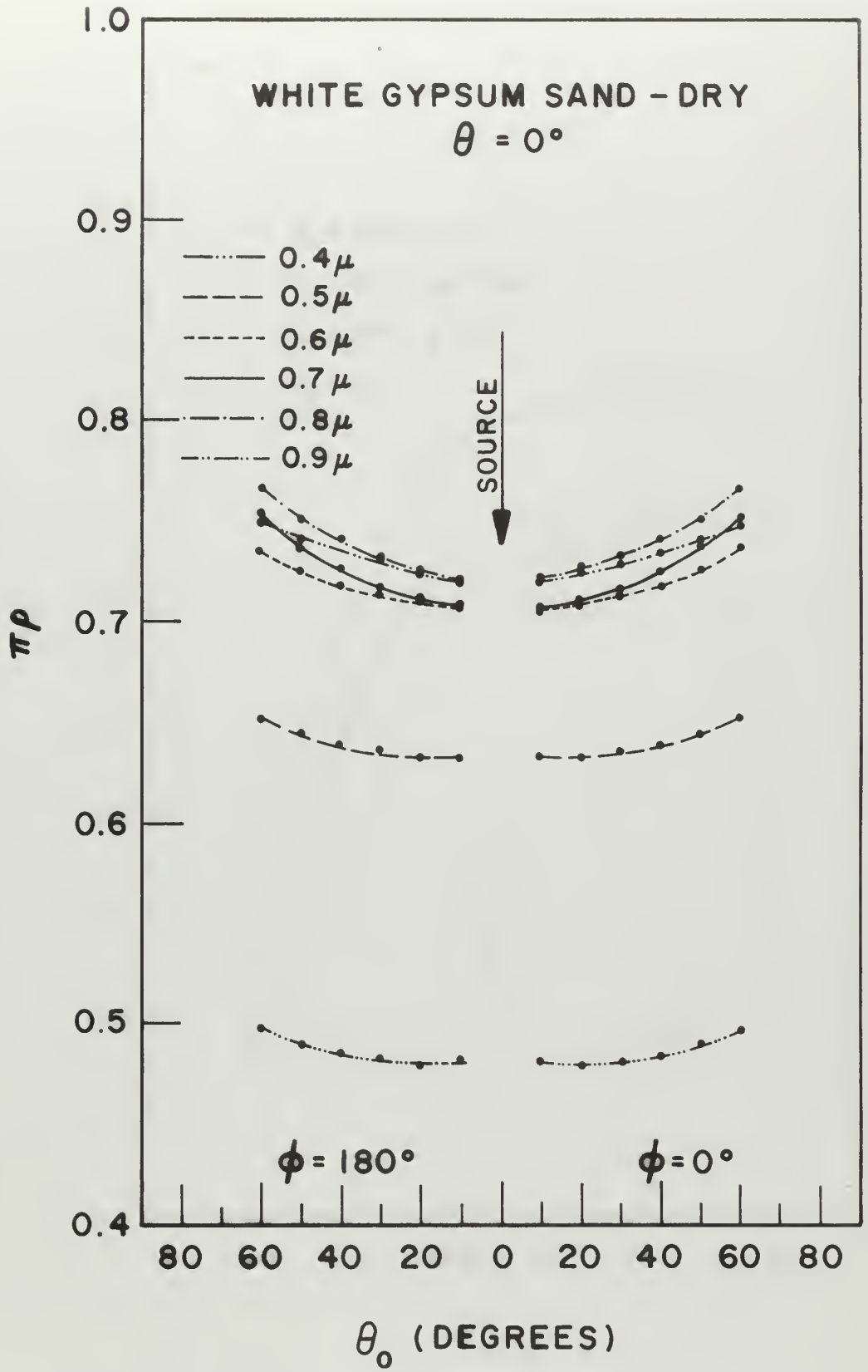


FIG. 8 REFLECTANCE OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF VIEW OF 0 DEGREES AS A FUNCTION OF THE ANGLE OF INCIDENCE.

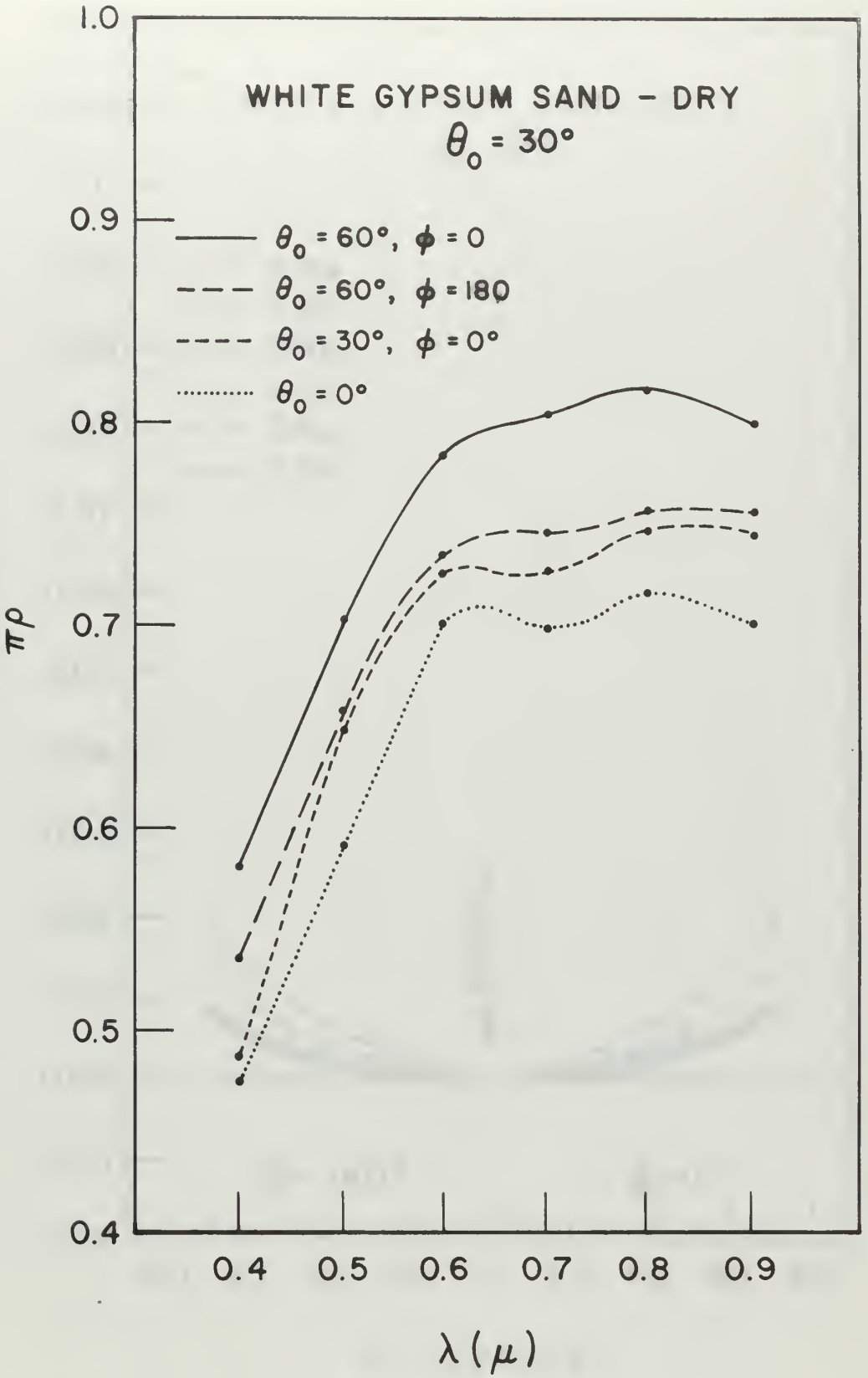


FIG. 9 REFLECTANCE OF DRY WHITE GYPSUM SAND AS A FUNCTION OF WAVELENGTH IN THE PRINCIPAL PLANE FOR AN ANGLE OF INCIDENCE OF 30 DEGREES.

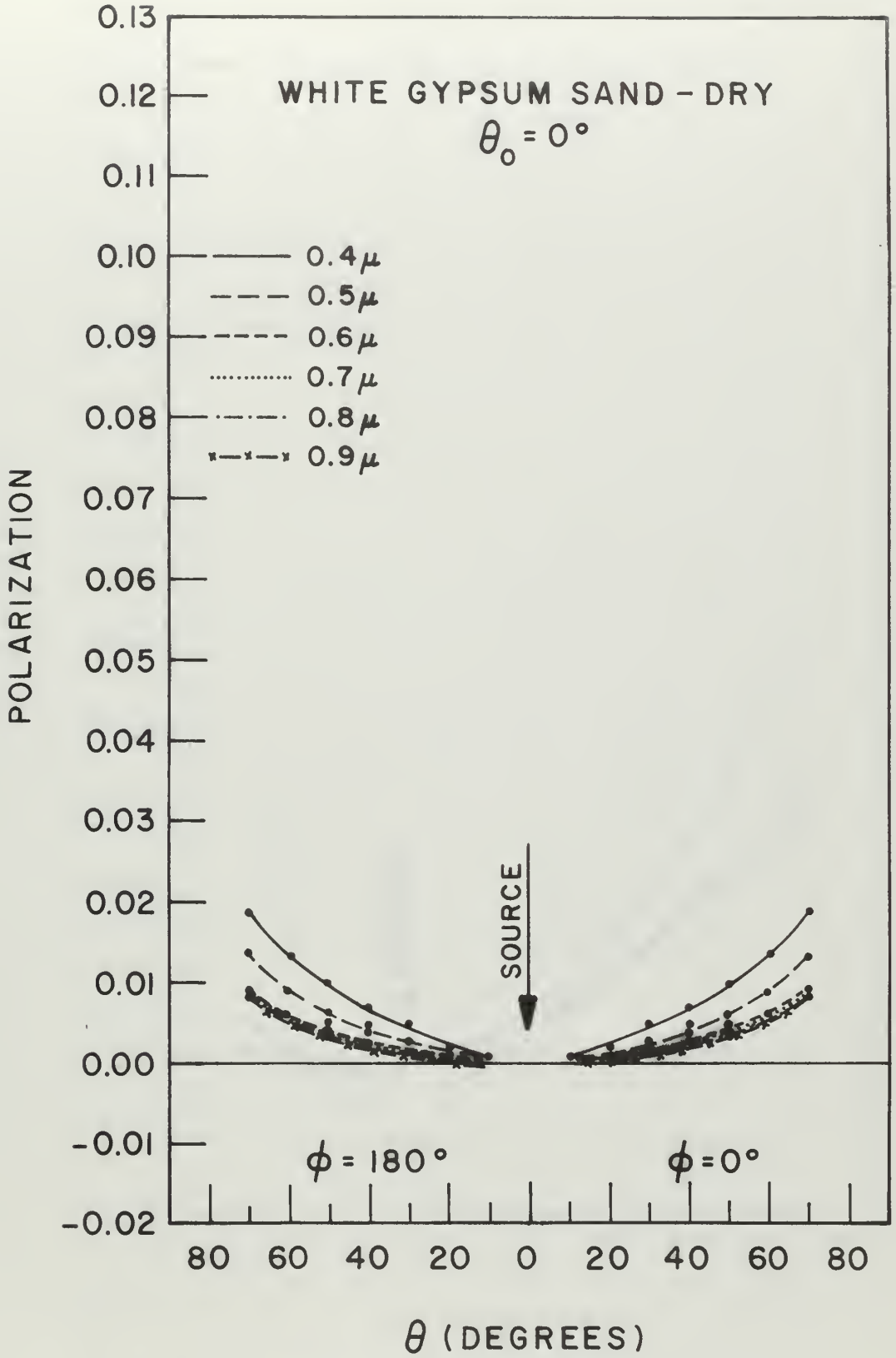


FIG. 10 POLARIZATION OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 0 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

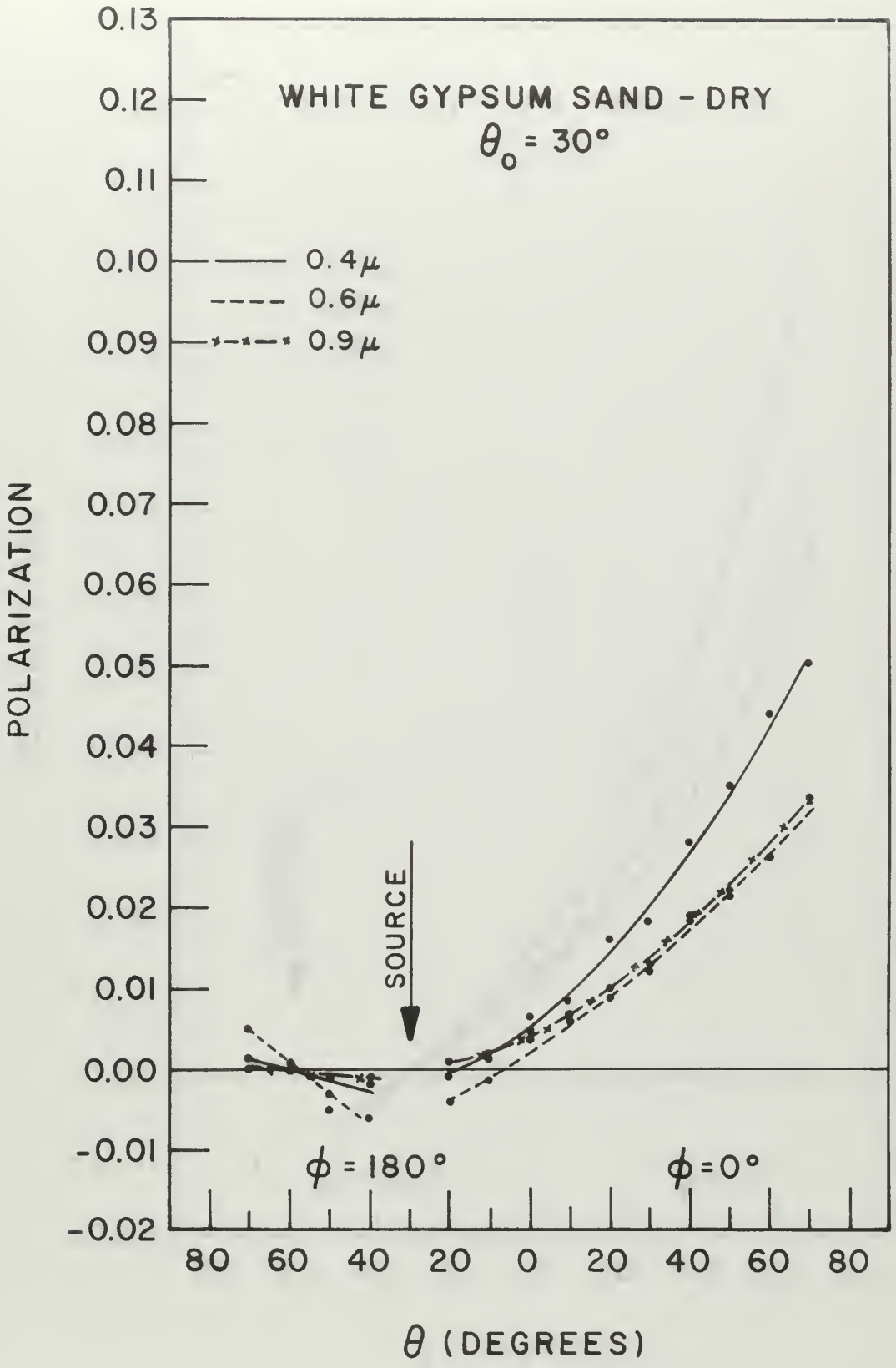


FIG. 11 POLARIZATION OD DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 30 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

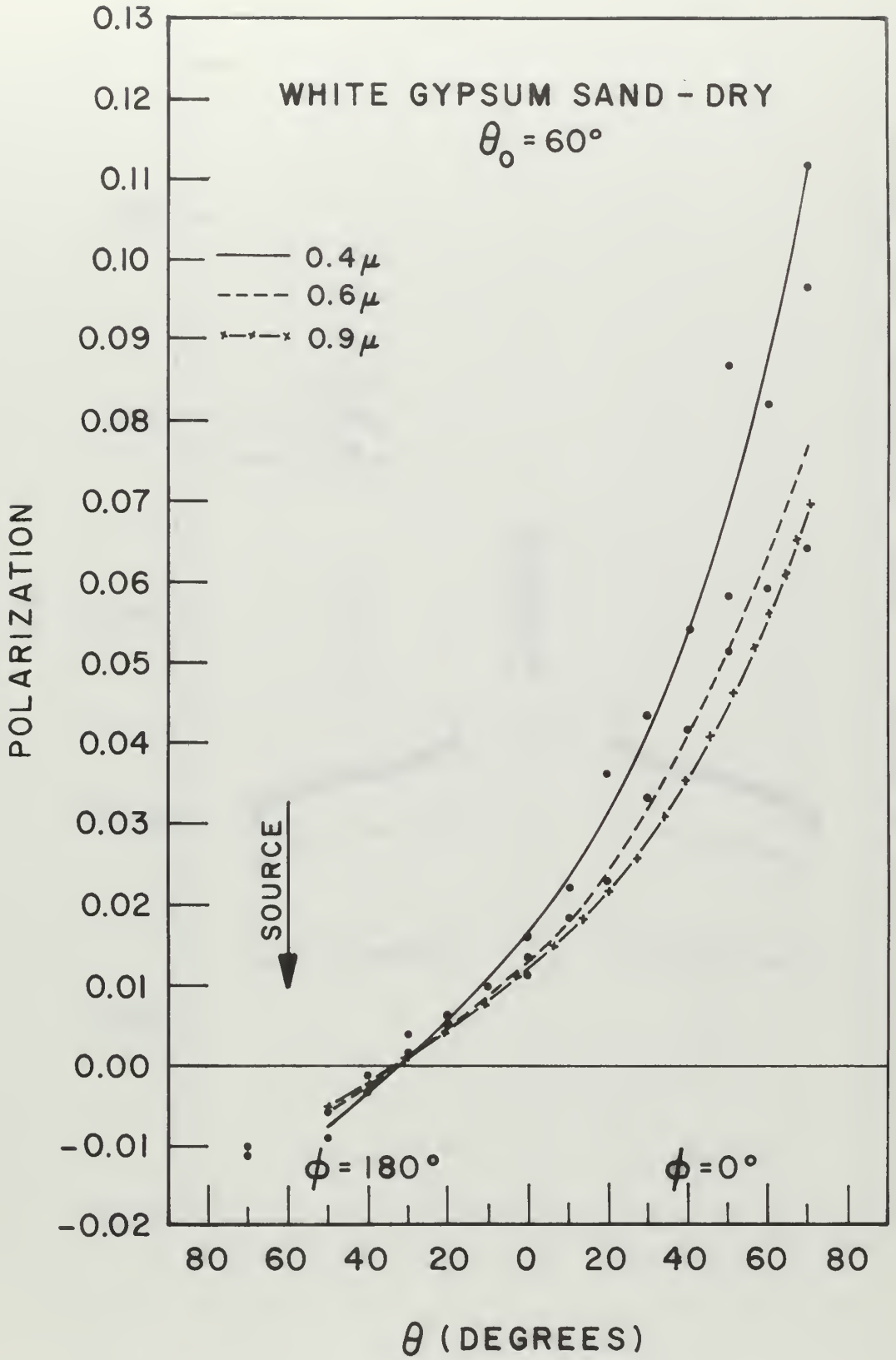


FIG. 12 POLARIZATION OF DRY WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 60 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

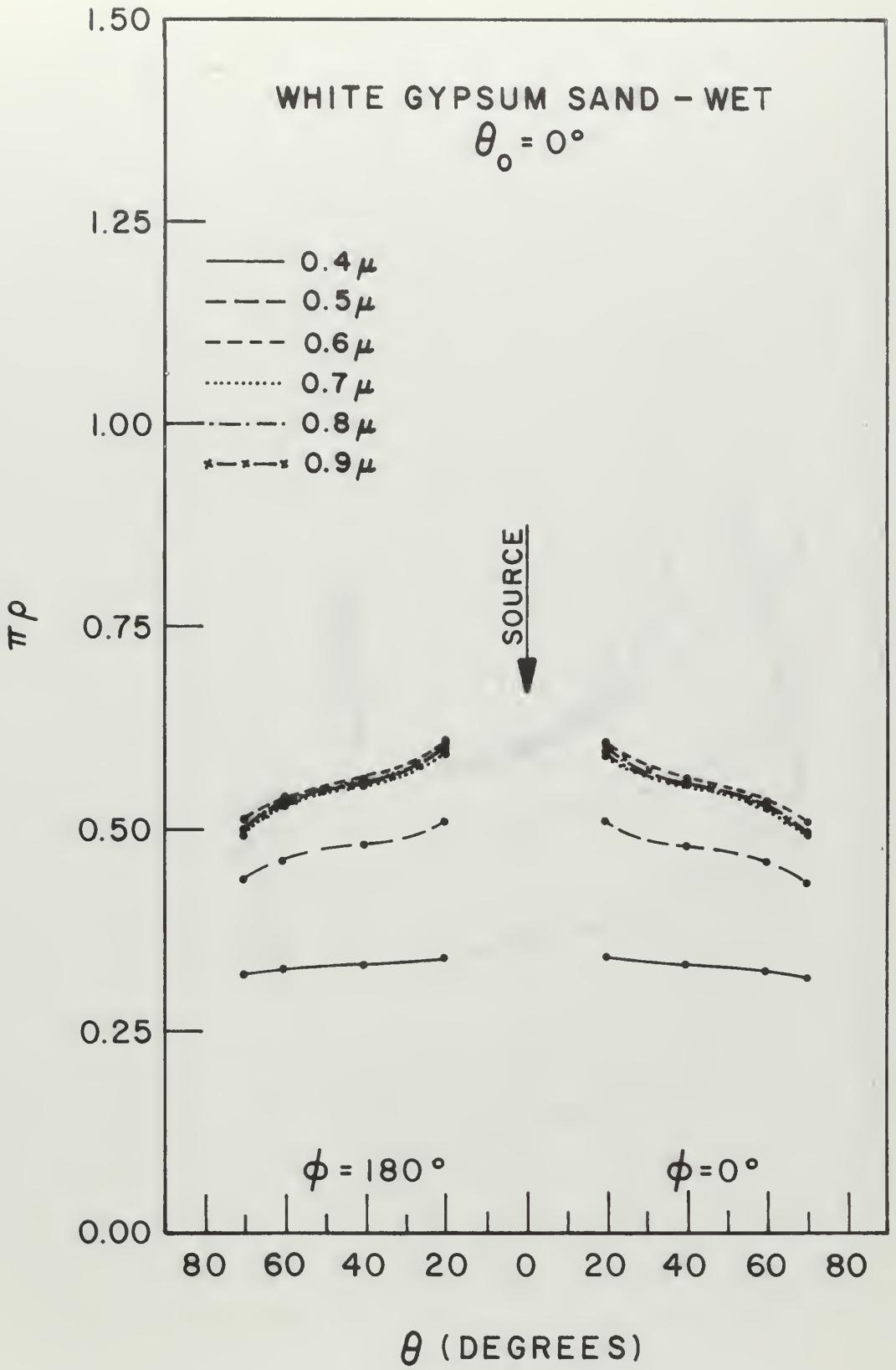


FIG. 13 RELFECTANCE OF WET WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 0 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

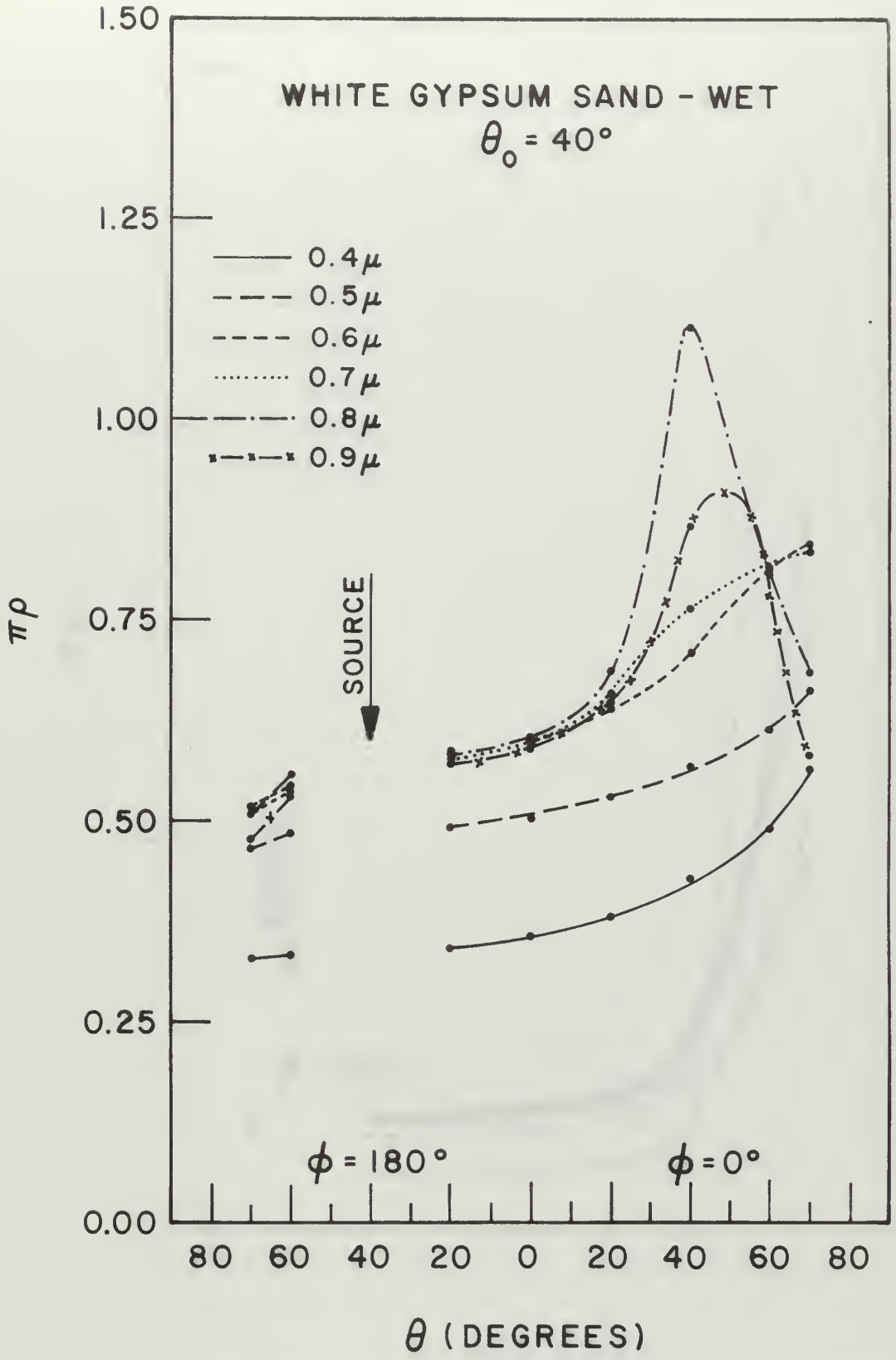


FIG. 14 REFLECTANCE OF WET WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 40 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

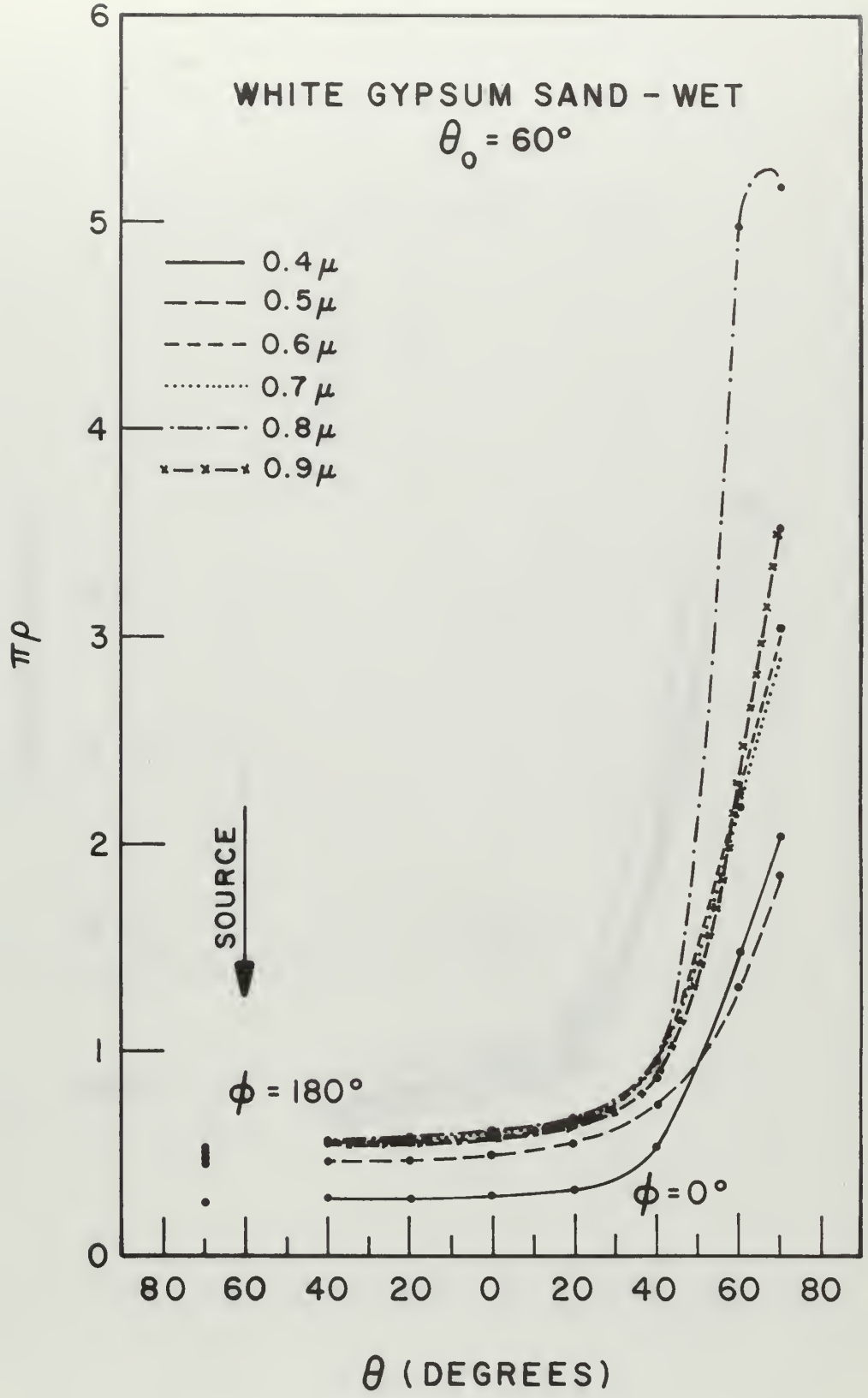


FIG. 15 REFLECTANCE OF WET WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 60 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

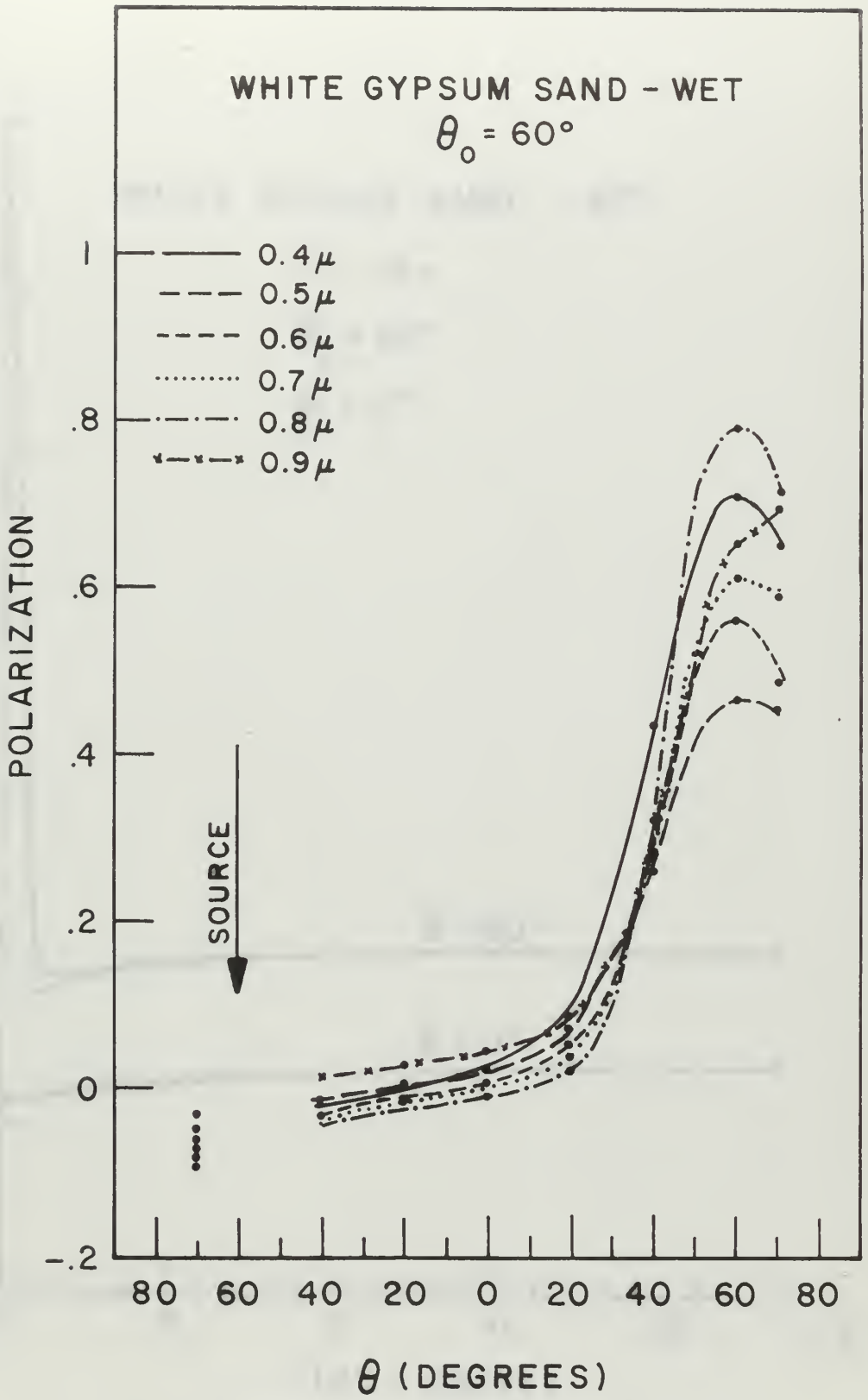


FIG. 16 POLARIZATION OF WET WHITE GYPSUM SAND AT VARIOUS WAVELENGTHS IN THE PRINCIPAL PLANE WITH AN ANGLE OF INCIDENCE OF 60 DEGREES AS A FUNCTION OF THE ANGLE OF VIEW.

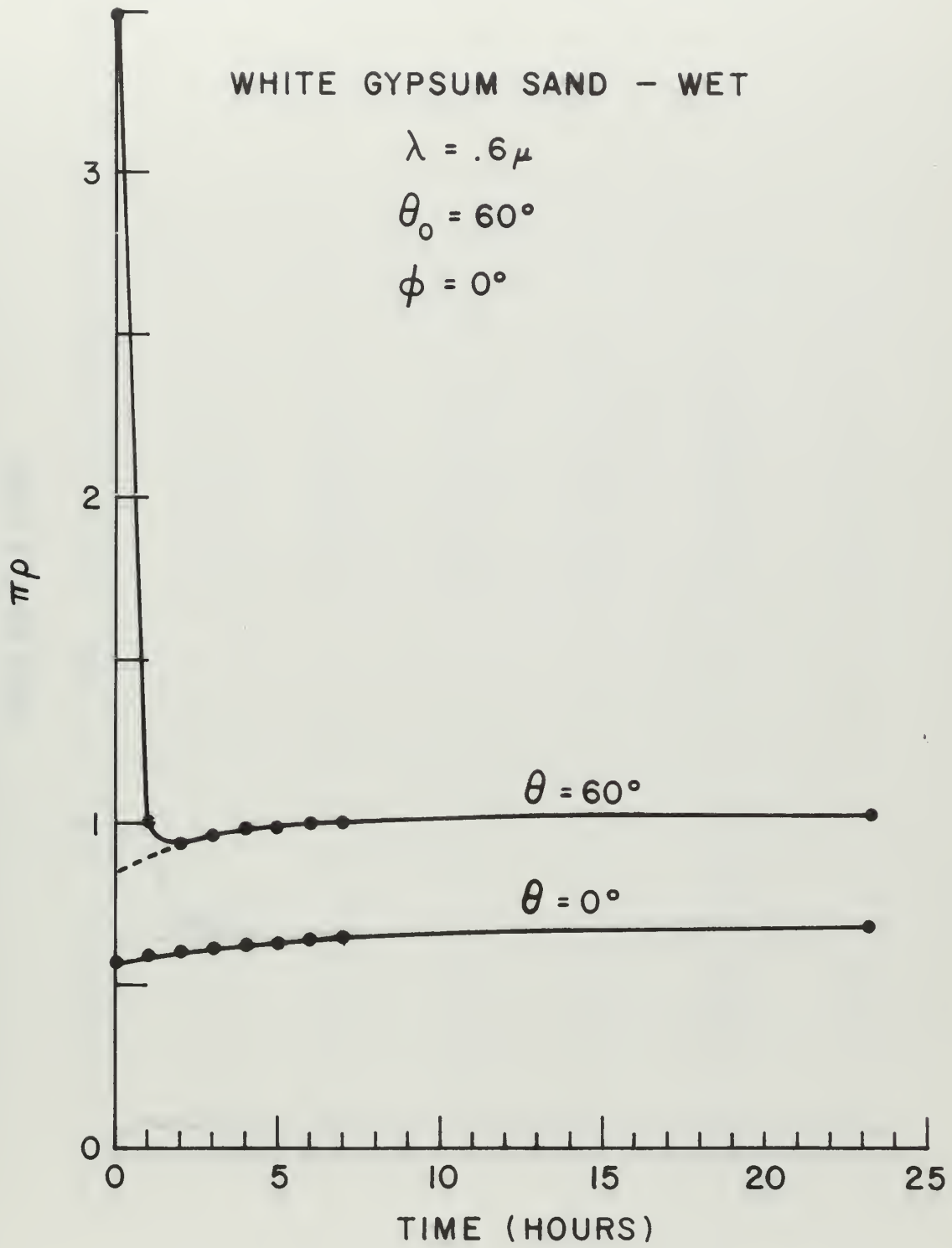


FIG. 17 REFLECTANCE OF WHITE GYPSUM SAND AS IT DRIES FROM A SATURATED STATE.

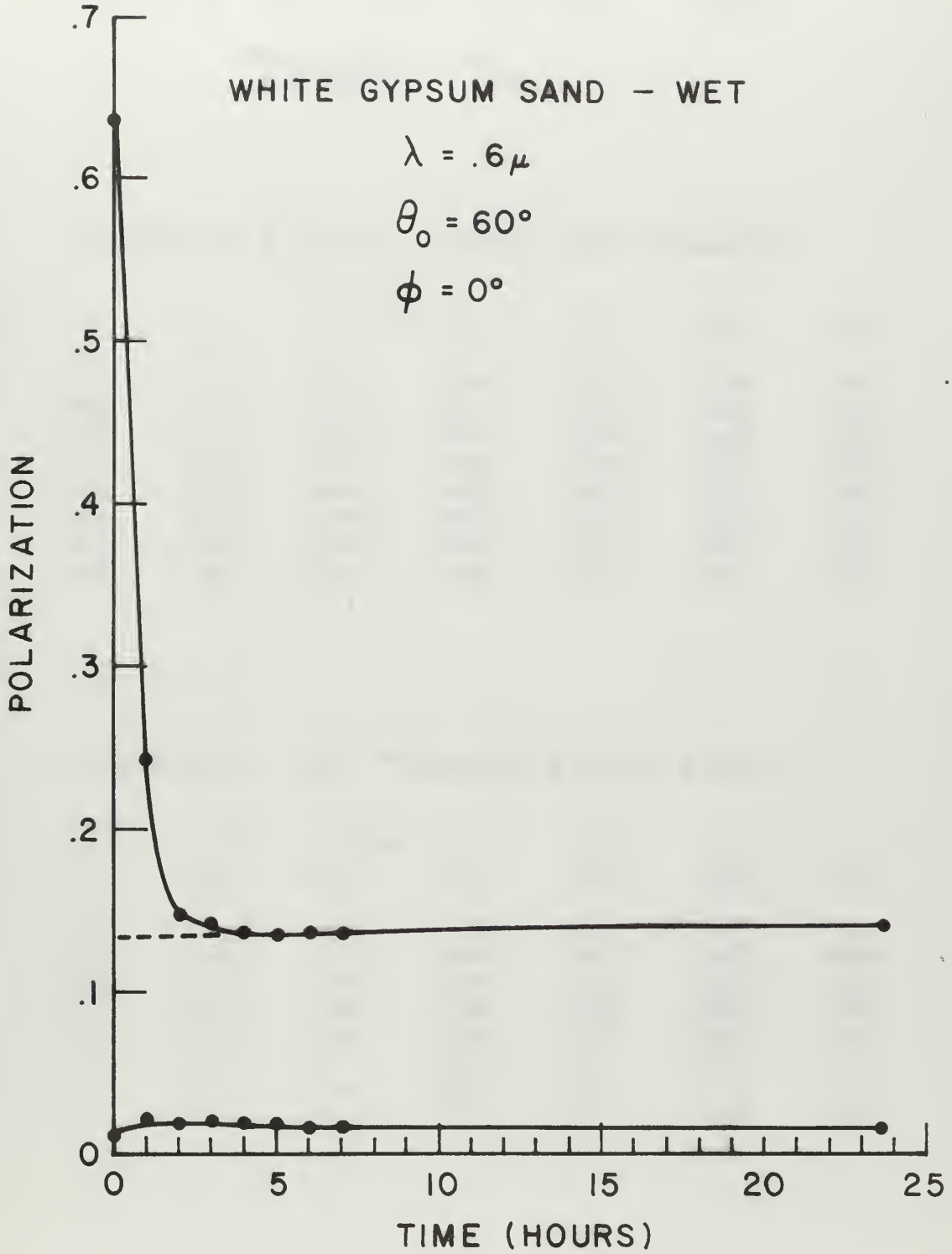


FIG. 18 POLARIZATION OF WHITE GYPSUM SAND AS IT DRIES FROM A SATURATED STATE.

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.478	.48	.482	.47	.481	.478	.478
20	.475	.477	.479	.477	.475	.473	.471
30	.476	.477	.479	.476	.473	.471	.469
40	.477	.479	.48	.478	.473	.47	.469
50	.481	.481	.483	.481	.476	.473	.471
60	.485	.486	.488	.482	.478	.474	.47
70	.488	.489	.49	.482	.476	.47	.467

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.004	.004	.002	.003	.003	.005	.004
20	.005	.005	.005	.004	.004	.004	.004
30	.007	.006	.006	.006	.005	.005	.005
40	.007	.009	.008	.008	.007	.008	.007
50	.011	.011	.01	.011	.01	.011	.01
60	.015	.013	.014	.014	.014	.013	.013
70	.02	.019	.019	.02	.019	.018	.018

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.483	.482	.481	.479	.481	.482	.483
10	.477	.479	.477	.479	.479	.483	---
20	.477	.479	.479	.479	.478	.482	.48
30	.478	.481	.481	.48	.478	.483	.473
40	.483	.485	.487	.482	.48	.476	.469
50	.486	.489	.491	.485	.483	.475	.468
60	.493	.495	.495	.489	.49	.476	.466
70	.5	.501	.498	.49	.483	.471	.46

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.002	.003	.005	.004	.005	.003	.002
10	.004	.005	.003	.003	.003	.003	---
20	.007	.007	.006	.004	.002	.003	.003
30	.009	.009	.011	.006	.003	.003	.005
40	.012	.014	.013	.009	.004	.003	.004
50	.017	.017	.016	.011	.007	.005	.004
60	.021	.02	.019	.015	.012	.008	.007
70	.027	.026	.025	.02	.013	.012	.011

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.471	.488	.479	.479	.479	.488	.471
10	.474	.488	.48	.479	.48	.488	.474
20	.474	.489	.481	.481	.484	.493	---
30	.486	.496	.492	.485	.49	.495	.485
40	.493	.504	.491	.49	.493	.495	.484
50	.505	.516	.493	.493	.496	.497	.488
60	.514	.526	.506	.498	.499	.494	.489
70	.529	.535	.519	.501	.497	.49	.482

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.005	.004	.003	.003	.003	.004	.005
10	.009	.007	.009	.003	.004	.004	.003
20	.01	.009	.01	.004	.003	.003	---
30	.017	.015	.014	.009	.002	.001	.003
40	.02	.019	.017	.009	.004	.001	.003
50	.026	.025	.02	.011	.004	.003	.002
60	.031	.028	.025	.017	.009	.004	.002
70	.038	.036	.03	.021	.013	.008	.005

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.471	.487	.481	.487	.481	.487	.471
10	.477	.485	.49	.487	.483	.489	.478
20	.483	.489	.49	.489	.485	.492	.479
30	.488	.499	.496	.491	.487	.499	---
40	.5	.51	.508	.496	.491	.505	.485
50	.519	.527	.521	.504	.495	.492	.483
60	.538	.539	.533	.511	.501	.509	.484
70	.558	.557	.527	.519	.499	.499	.488

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	009	.008	.004	.006	.004	.008	.009
10	.01	.011	.01	.004	.004	.001	.004
20	.017	.016	.016	.007	.002	.001	.002
30	.019	.019	.016	.01	.002	.003	---
40	.029	.024	.026	.013	.003	.002	.003
50	.036	.03	.027	.017	.007	.002	.004
60	.045	.044	.03	.02	.01	.004	.01
70	.051	.048	.038	.025	.012	.007	.003

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.482	.486	.486	.489	.486	.486	.482
10	.489	.49	.489	.49	.485	.486	.484
20	.497	.498	.495	.493	.491	.489	.492
30	.516	.51	.505	.499	.493	.497	.505
40	.527	.526	.517	.507	.499	.505	---
50	.555	.546	.532	.517	.507	.51	.516
60	.582	.574	.548	.529	.513	.512	.515
70	.618	.603	.569	.539	.515	.509	.506

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	.012	.012	.01	.012	.012	.007
10	.015	.015	.017	.008	.008	.009	.008
20	.02	.021	.021	.01	.006	.006	.004
30	.032	.026	.024	.012	.003	.005	.003
40	.034	.033	.027	.017	.006	.003	---
50	.05	.041	.036	.02	.008	.004	.005
60	.058	.049	.039	.021	.011	.005	.005
70	.071	.063	.045	.03	.014	.005	.004

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.485	.488	.489	.492	.489	.488	.485
10	.493	.493	.492	.494	.489	.486	.484
20	.505	.502	.519	.498	.492	.489	.489
30	.521	.518	.511	.505	.497	.497	.499
40	.55	.551	.526	.515	.505	.509	.515
50	.573	.566	.545	.528	.515	.519	---
60	.62	.598	.568	.545	.526	.527	.537
70	.677	.646	.597	.561	.537	.528	.528

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.012	.011	.011	.013	.011	.011	.012
10	.018	.016	.016	.012	.009	.007	.007
20	.025	.023	.034	.014	.009	.006	.003
30	.032	.031	.022	.016	.008	.003	---
40	.051	.054	.028	.018	.012	.004	.003
50	.053	.048	.033	.022	.014	.007	---
60	.077	.055	.038	.026	.017	.009	.007
70	.09	.074	.047	.032	.021	.011	.007

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.49	.493	.498	.502	.498	.493	.49
10	.5	.501	.502	.505	.497	.489	.488
20	.52	.517	.513	.509	.499	.493	.492
30	.54	.537	.526	.519	.508	.504	.5
40	.572	.565	.551	.535	.519	.515	.518
50	.63	.6	.572	.551	.538	.535	.545
60	.68	.649	.605	.574	.554	.553	---
70	.791	.713	.642	.599	.573	.568	.581

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.017	.018	.017	.018	.017	.018	.017
10	.023	.024	.02	.017	.014	.013	.011
20	.037	.032	.026	.02	.012	.01	.007
30	.044	.039	.029	.021	.013	.006	.003
40	.055	.051	.042	.025	.015	.006	.001
50	.088	.057	.038	.027	.017	.007	.007
60	.083	.065	.045	.031	.02	.01	---
70	.113	.071	.048	.035	.024	.013	.009

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.632	.635	.638	.624	.637	.635	.631
20	.628	.633	.634	.632	.63	.627	.623
30	.627	.631	.633	.628	.626	.623	.619
40	.627	.63	.632	.627	.624	.62	.617
50	.628	.631	.633	.627	.624	.62	.614
60	.627	.63	.633	.622	.621	.615	.607
70	.625	.627	.628	.614	.611	.602	.594

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.005	.005	.006	.006	.005	.005	.006
20	.006	.005	.006	.007	.007	.005	.006
30	.007	.007	.006	.006	.007	.006	.006
40	.009	.009	.008	.008	.007	.007	.008
50	.01	.01	.01	.009	.008	.008	.007
60	.012	.012	.014	.012	.012	.01	.01
70	.015	.017	.016	.018	.016	.013	.015

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.633	.632	.632	.632	.632	.632	.633
10	.628	.629	.629	.63	.631	.633	---
20	.63	.629	.629	.628	.628	.629	.631
30	.63	.63	.631	.628	.625	.625	.625
40	.634	.635	.633	.628	.623	.621	.62
50	.637	.637	.635	.628	.623	.617	.618
60	.64	.639	.637	.628	.62	.612	.611
70	.642	.64	.635	.622	.608	.6	.598

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.004	.004	.006	.005	.006	.004	.004
10	.007	.006	.006	.005	.005	.005	---
20	.007	.007	.008	.006	.004	.005	.007
30	.009	.009	.008	.005	.004	.006	.004
40	.01	.011	.011	.007	.004	.005	.005
50	.012	.014	.014	.009	.005	.005	.004
60	.015	.016	.016	.011	.007	.006	.007
70	.022	.021	.019	.013	.008	.008	.008

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.631	.631	.633	.634	.633	.631	.631
10	.633	.632	.632	.633	.632	.633	.633
20	.633	.633	.633	.634	.631	.634	---
30	.64	.638	.638	.634	.631	.632	.634
40	.646	.644	.643	.636	.629	.629	.627
50	.653	.653	.647	.638	.628	.626	.623
60	.661	.661	.651	.638	.625	.618	.616
70	.669	.666	.653	.634	.615	.607	.598

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	.006	.008	.006	.008	.006	.007
10	.007	.009	.007	.005	.006	.005	.005
20	.009	.01	.01	.006	.004	.005	---
30	.012	.012	.013	.006	.004	.004	.005
40	.016	.016	.015	.008	.002	.004	.005
50	.018	.02	.018	.009	.002	.003	.004
60	.023	.024	.02	.012	.005	.002	.003
70	.029	.028	.024	.015	.007	.005	.006

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.632	.634	.635	.639	.635	.634	.632
10	.634	.635	.637	.638	.635	.634	.633
20	.643	.641	.639	.638	.635	.636	.637
30	.648	.648	.646	.641	.637	.638	---
40	.663	.659	.653	.645	.637	.64	.642
50	.676	.673	.663	.649	.637	.636	.636
60	.691	.688	.671	.652	.637	.631	.628
70	.708	.7	.679	.653	.629	.619	.613

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	.01	.009	.007	.009	.01	.008
10	.01	.011	.011	.005	.006	.007	.006
20	.014	.015	.013	.005	.004	.005	.004
30	.017	.016	.017	.007	.003	.005	---
40	.023	.02	.018	.009	.001	.003	.006
50	.028	.026	.023	.011	.001	.003	.006
60	.034	.032	.026	.015	.004	.002	.006
70	.041	.038	.032	.018	.006	.001	.004

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.636	.638	.639	.644	.639	.638	.636
10	.64	.642	.643	.643	.638	.638	.633
20	.649	.651	.647	.646	.644	.64	.638
30	.666	.663	.656	.65	.642	.644	.644
40	.68	.678	.668	.656	.647	.648	---
50	.707	.698	.681	.664	.65	.65	.653
60	.731	.724	.697	.671	.653	.647	.647
70	.764	.748	.709	.67	.648	.636	.634

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.009	.014	.01	.002	.01	.014	.009
10	.013	.015	.014	.006	.008	.009	.008
20	.017	.019	.016	.007	.007	.006	.006
30	.025	.023	.02	.01	.004	.006	.005
40	.028	.028	.022	.011	.004	.005	---
50	.041	.034	.026	.015	.005	.005	.006
60	.047	.045	.033	.018	.008	.004	.006
70	.056	.051	.037	.022	.011	.004	.005

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.642	.645	.647	.649	.647	.645	.642
10	.651	.651	.651	.651	.656	.644	.64
20	.664	.662	.668	.655	.658	.652	.644
30	.683	.68	.671	.663	.657	.659	.655
40	.707	.7	.686	.673	.665	.668	.668
50	.738	.728	.704	.684	.67	.674	---
60	.788	.763	.726	.697	.678	.676	.68
70	.841	.813	.752	.707	.68	.674	.669

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.013	.015	.014	.011	.014	.015	.013
10	.017	.017	.017	.009	.013	.012	.01
20	.023	.025	.026	.011	.011	.008	.007
30	.03	.029	.024	.012	.007	.006	.005
40	.036	.035	.027	.016	.006	.008	.006
50	.045	.044	.032	.017	.009	.008	---
60	.067	.051	.035	.021	.01	.007	.008
70	.073	.066	.042	.025	.012	.004	.008

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.646	.649	.656	.659	.656	.649	.646
10	.659	.661	.664	.662	.658	.648	.644
20	.676	.677	.674	.668	.671	.656	.646
30	.702	.698	.693	.678	.665	.659	.655
40	.737	.729	.715	.693	.677	.673	.672
50	.782	.769	.737	.71	.703	.698	.706
60	.851	.819	.769	.731	.709	.708	---
70	.983	.89	.81	.753	.73	.725	.729

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.017	.021	.017	.013	.017	.021	.017
10	.022	.025	.022	.012	.011	.015	.012
20	.028	.03	.026	.014	.011	.019	.01
30	.037	.036	.031	.015	.01	.003	.007
40	.048	.045	.038	.02	.011	.007	.006
50	.059	.051	.038	.022	.016	.017	.003
60	.072	.058	.039	.024	.012	.004	---
70	.107	.064	.046	.029	.011	.011	.011

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.708	.711	.712	.709	.709	.708	.706
20	.704	.706	.71	.706	.703	.702	.7
30	.702	.705	.705	.701	.698	.697	.694
40	.7	.703	.703	.698	.695	.692	.691
50	.697	.7	.701	.695	.691	.688	.684
60	.694	.696	.696	.681	.683	.678	.673
70	.685	.686	.687	.671	.666	.661	.654

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.001	.002	.002	.002	.002	.002	.002
20	.003	.001	.003	.002	.003	.002	.002
30	.003	.003	.003	.003	.005	.003	.004
40	.005	.004	.006	.004	.005	.005	.005
50	.006	.005	.006	.005	.006	.006	.006
60	.007	.007	.009	.008	.008	.006	.007
70	.01	.01	.011	.01	.01	.01	.01

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.706	.707	.708	.709	.708	.707	.706
10	.703	.704	.706	.707	.707	.708	---
20	.703	.703	.704	.703	.704	.703	.703
30	.704	.704	.705	.702	.698	.697	.696
40	.704	.705	.707	.7	.694	.693	.69
50	.704	.706	.704	.697	.689	.684	.682
60	.705	.705	.702	.693	.682	.675	.67
70	.7	.699	.694	.682	.665	.655	.646

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.002	.002	.002	.002	.002	.002	.002
10	.003	.002	.001	.002	.003	.002	---
20	.004	.004	.003	.002	.003	.002	.001
30	.005	.005	.005	.004	.002	.002	---
40	.007	.006	.007	.005	.005	.003	.002
50	.009	.009	.008	.007	.006	.003	.002
60	.012	.011	.01	.008	.007	.005	.004
70	.017	.016	.014	.012	.009	.006	.005

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.71	.713	.714	.715	.714	.713	.71
10	.709	.711	.712	.713	.715	.713	.714
20	.71	.711	.716	.716	.711	.715	---
30	.715	.714	.714	.717	.71	.716	.713
40	.72	.719	.716	.717	.712	.714	.705
50	.725	.724	.717	.714	.712	.707	.695
60	.728	.727	.716	.717	.708	.698	.681
70	.73	.728	.713	.702	.693	.69	.656

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.003	.003	.006	.004	.006	.003	.003
10	.004	.004	.001	.002	.006	.006	.002
20	.006	.005	.005	.003	.003	.005	---
30	.01	.008	.003	.004	.003	.004	.004
40	.012	.012	.009	.01	.006	.002	.002
50	.015	.015	.012	.01	.008	.003	.003
60	.018	.018	.014	.009	.006	.005	.002
70	.023	.023	.015	.015	.018	.011	.004

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.712	.709	.713	.717	.713	.709	.712
10	.714	.711	.715	.716	.714	.709	.72
20	.718	.715	.718	.716	.714	.711	.724
30	.724	.721	.723	.718	.712	.711	---
40	.736	.729	.73	.721	.711	.712	.725
50	.746	.738	.735	.722	.709	.702	.707
60	.756	.751	.74	.722	.703	.692	.705
70	.769	.758	.742	.713	.687	.671	.677

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.005	.004	.002	.001	.002	.004	.005
10	.008	.007	.005	.003	.001	.002	.003
20	.011	.009	.007	.004	.001	.002	.003
30	.013	.011	.009	.006	.004	.001	---
40	.019	.016	.013	.009	.006	.002	.006
50	.022	.019	.015	.011	.007	.004	.004
60	.027	.025	.018	.014	.009	.006	.013
70	.034	.032	.023	.018	.012	.008	.005

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.714	.716	.72	.723	.72	.716	.714
10	.719	.721	.722	.724	.719	.716	.714
20	.728	.728	.728	.725	.72	.716	.715
30	.739	.738	.736	.729	.721	.719	.724
40	.754	.752	.746	.733	.723	.722	---
50	.777	.768	.757	.738	.723	.72	.722
60	.8	.789	.769	.741	.722	.713	.709
70	.824	.81	.776	.742	.707	.692	.686

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	.007	.004	.003	.004	.007	.007
10	.009	.009	.007	.004	.002	.003	.005
20	.015	.014	.01	.006	.003	.002	.001
30	.018	.016	.013	.008	.005	.002	---
40	.023	.02	.018	.011	.005	.003	---
50	.033	.026	.02	.012	.009	.004	.004
60	.042	.034	.024	.017	.012	.007	.004
70	.049	.04	.029	.021	.015	.008	.004

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.72	.723	.73	.728	.73	.723	.72
10	.728	.73	.735	.728	.747	.72	.717
20	.742	.741	.749	.734	.749	.72	.719
30	.76	.758	.752	.739	.753	.726	.725
40	.782	.778	.765	.746	.75	.736	.737
50	.812	.804	.78	.755	.747	.738	---
60	.858	.836	.799	.765	.751	.737	.744
70	.921	.877	.82	.77	.746	.726	.724

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.01	.01	.008	.004	.008	.01	.01
10	.015	.012	.01	.008	.01	.007	.007
20	.02	.017	.017	.009	.003	.003	.004
30	.026	.023	.017	.011	.009	.001	.001
40	.032	.029	.021	.013	.005	.005	.003
50	.041	.035	.023	.017	.012	.005	---
60	.059	.041	.028	.02	.014	.007	.005
70	.076	.052	.035	.024	.019	.009	.007

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.728	.732	.739	.742	.739	.732	.728
10	.74	.743	.746	.744	.735	.727	.725
20	.758	.758	.757	.749	.738	.727	.724
30	.783	.78	.776	.758	.743	.734	.732
40	.819	.81	.797	.771	.753	.745	.745
50	.863	.849	.818	.786	.767	.762	.77
60	.931	.899	.848	.805	.777	.771	---
70	1.058	.967	.885	.821	.784	.774	.783

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.014	.012	.011	.011	.011	.012	.014
10	.019	.018	.015	.011	.008	.01	.011
20	.024	.022	.018	.012	.007	.006	.006
30	.034	.027	.025	.015	.007	.004	.002
40	.043	.037	.029	.017	.01	.004	.002
50	.052	.043	.029	.021	.014	.006	.005
60	.065	.049	.032	.024	.016	.008	---
70	.098	.056	.041	.028	.019	.011	.009

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.706	.709	.708	.707	.714	.713	.709
20	.701	.704	.703	.702	.708	.707	.704
30	.698	.702	.699	.698	.7	.701	.698
40	.695	.697	.695	.694	.696	.695	.69
50	.69	.693	.691	.687	.69	.689	.682
60	.683	.685	.683	.641	.679	.676	.668
70	.669	.671	.668	.662	.658	.653	.641

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.008	.007	.008	.008	.008	.008	.008
20	.008	.006	.007	.007	.006	.007	.008
30	.009	.007	.007	.006	.005	.007	.007
40	.007	.006	.006	.006	.007	.006	.006
50	.006	.007	.006	.005	.006	.006	.005
60	.008	.007	.007	.011	.006	.005	.006
70	.007	.007	.007	.008	.006	.006	.006

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.706	.708	.709	.706	.709	.708	.706
10	701	.711	.705	.705	.709	.706	---
20	699	702	.704	702	.706	.705	.705
30	.699	699	.701	.698	.706	.701	.697
40	.7	.703	699	.695	.696	.695	.688
50	.699	698	.695	691	.692	689	.678
60	.695	699	.691	685	.68	.665	.663
70	687	687	.68	669	.653	.638	.631

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	008	.006	.008	.008	.008	.006	.008
10	007	.008	.008	.008	.009	.007	---
20	007	.008	.009	.007	.008	.008	.009
30	.006	009	.009	.008	.006	.007	.009
40	007	008	.01	.007	.006	.006	.009
50	008	.01	.011	.006	.004	.006	.009
60	.008	.013	.011	.006	.004	.005	.007
70	.011	.013	.015	.006	.001	.004	.007

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.711	.709	.712	.713	.712	.709	.711
10	.709	.71	.715	.713	.713	.71	.713
20	.711	.71	.714	.711	.712	.714	---
30	.718	.715	.712	.709	.71	.708	.713
40	.719	.719	.714	.71	.705	.702	.701
50	.722	723	.715	.708	.698	.691	.689
60	725	722	.715	.702	.686	.675	.674
70	719	.719	.707	.684	.663	.644	.638

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	009	.009	.008	.009	.009	.007
10	.007	.009	.01	.008	.008	.008	.009
20	007	.009	.01	009	.008	.008	---
30	.007	.011	.012	.009	.006	.009	.008
40	01	.012	.013	.009	.008	.009	.01
50	011	.016	.015	.008	.007	.008	.01
60	013	.015	.018	.01	.006	.008	.009
70	.018	02	.021	.012	.005	.008	.009

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.714	715	.716	.719	.716	.715	.714
10	.719	.717	.717	.719	.717	.717	.717
20	.724	.724	.721	.719	.719	.717	.721
30	.727	.728	.724	.72	.717	.716	---
40	.737	735	.728	.72	.715	.711	.713
50	.747	743	.733	.721	.711	.701	.699
60	.757	752	.736	.718	699	.685	677
70	.766	.759	.738	.705	.672	.65	643

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.006	.01	.011	01	.011	.01	.006
10	.007	.01	.012	.009	.01	.008	007
20	.007	.011	.013	.01	009	.009	.008
30	.01	.014	.015	.011	.01	.009	---
40	013	.018	.017	.012	009	.01	012
50	017	.019	.02	.013	01	.011	.013
60	021	.023	.023	.015	.011	.009	.012
70	.028	.029	.028	.019	.01	.01	.012

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.721	.727	.727	.727	.727	.727	.721
10	.727	.731	.731	.729	.727	.725	.722
20	.738	.74	.737	.732	.728	.727	.724
30	.75	.75	.743	.736	.732	.73	.73
40	.764	.764	.752	.739	.731	.729	---
50	.784	.779	.761	.742	.729	.723	.724
60	.806	.796	.772	.744	.724	.708	.704
70	.833	.817	.781	.732	.702	.675	.663

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.006	.012	.013	.012	.013	.012	.006
10	.007	.012	.016	.013	.012	.01	.007
20	.011	.015	.017	.013	.011	.011	.008
30	.015	.019	.02	.015	.011	.011	.01
40	.017	.021	.023	.015	.013	.012	---
50	.026	.026	.026	.017	.013	.013	.013
60	.031	.032	.03	.02	.015	.014	.015
70	.04	.04	.038	.022	.016	.013	.015

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.733	.737	.738	.742	.738	.737	.733
10	.743	.747	.744	.743	.737	.736	.729
20	.758	759	.751	747	.739	.733	.729
30	.779	773	.761	752	.743	.739	.735
40	804	793	.775	759	.745	.744	.748
50	832	822	.789	.769	.751	.749	---
60	.876	856	808	.774	.748	.739	.741
70	.937	899	828	.775	.731	.714	.704

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	.013	.017	.015	.017	.013	.008
10	01	.017	02	.015	.015	.011	006
20	015	.019	.022	.015	.014	.012	.006
30	021	.025	.023	.018	.014	.012	.01
40	029	029	027	.018	.014	.013	.011
50	.036	.037	.031	.022	.016	.014	---
60	.046	045	.034	024	.02	.017	.017
70	.061	.057	.039	029	.022	.017	.018

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.747	751	.756	758	.756	.751	.747
10	.76	761	.763	.761	.755	.744	.74
20	.78	.779	.774	765	.758	.745	.739
30	.806	.801	.789	774	.761	.752	.745
40	.847	.83	.812	789	.769	.76	.757
50	.899	878	.834	804	.778	.772	777
60	.97	.925	.86	.817	.784	.78	---
70	1.085	1.004	.899	.831	.78	.765	.775

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	01	.018	02	.02	.02	.018	.01
10	.014	.021	.025	.019	.019	.016	.009
20	021	.026	026	.02	.019	.014	.007
30	028	032	.03	.022	.017	.013	.007
40	.041	036	.035	.025	.018	.014	.009
50	055	054	.038	.028	.02	.016	.013
60	.066	.057	.04	.03	.022	.016	---
70	.078	07	.046	.036	.025	.019	.02

WHITE GYPSUM SAND — DRY

THETA ZERO = 80
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.791	.805	.819	.834	.819	.805	.791
10	.822	.828	.833	.839	.814	.793	.777
20	.863	.862	.855	.848	.817	.79	.773
30	.924	.909	.885	.866	.828	.795	.779
40	1.018	.975	.923	.893	.85	.822	.796
50	1.169	1.067	.977	.931	.879	.847	.827
60	1.486	1.202	1.053	.983	.926	.893	.887
70	2.392	1.441	1.182	1.06	.988	.96	.983

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.021	.031	.033	.031	.033	.031	.021
10	.032	.039	.038	.032	.03	.026	.016
20	.046	.048	.043	.031	.027	.022	.009
30	.064	.057	.049	.032	.025	.018	.008
40	.085	.068	.051	.033	.026	.019	.008
50	.104	.078	.054	.037	.026	.019	.01
60	.133	.074	.055	.04	.031	.019	.014
70	.179	.075	.067	.047	.033	.022	.017

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.722	.727	.726	.723	.728	.728	.724
20	.72	.723	.723	.717	.721	.72	.717
30	.715	.719	.718	.715	.717	.713	.709
40	.71	.714	.713	.711	.713	.708	.702
50	.705	.709	.708	.704	.706	.7	.694
60	.698	.702	.7	.693	.693	.684	.679
70	.683	.687	.685	.671	.665	.655	.648

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.009	.007	.009	.008	.008	.008	.008
20	.007	.008	.007	.007	.007	.009	.009
30	.007	.007	.007	.007	.006	.006	.007
40	.008	.007	.006	.006	.005	.007	.006
50	.007	.007	.007	.007	.006	.005	.007
60	.009	.007	.007	.007	.006	.007	.007
70	.008	.007	.007	.008	.006	.007	.006

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	718	719	722	.721	722	.719	.718
10	715	.716	.722	721	.723	.721	---
20	714	.714	721	.716	717	.715	715
30	.713	713	.717	.714	716	.71	.707
40	.713	.714	.715	.711	.708	.704	.699
50	71	.709	.711	.706	.701	.694	.687
60	707	.706	.705	.697	.687	.675	.669
70	696	696	.693	.68	66	.644	.637

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	008	.007	.008	.007	.008	.008
10	.008	.007	.008	008	.008	.007	---
20	006	.008	.008	.007	.007	.009	.008
30	006	008	.008	.006	.006	.008	.009
40	.007	008	.009	.006	.005	.008	.008
50	.007	.009	.01	.006	.004	.006	.009
60	.009	.011	.011	006	.003	.005	.007
70	011	013	.013	008	---	.004	.006

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.726	.725	725	.728	.725	.725	726
10	727	.726	.725	.727	.725	.727	.727
20	.727	.728	725	.726	.723	.727	---
30	.733	731	727	.727	.72	.721	.722
40	736	.735	.731	.725	.716	.715	.712
50	.742	.742	.731	.724	.709	.705	.696
60	.744	.743	.729	.715	.695	.687	.678
70	743	.74	.724	.699	.663	.65	.639

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	.008	.008	.007	.008	.008	.007
10	006	.009	.009	.008	.008	.008	.008
20	006	.009	.01	.008	.007	.007	---
30	008	.01	.011	.009	.007	.008	.008
40	.009	.012	013	008	.007	.008	.011
50	.012	.016	.015	008	.005	.008	.009
60	.014	.017	.016	.01	.007	.007	.009
70	.019	.021	.021	.013	.004	.005	.008

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	73	73	.733	.735	.733	.73	.73
10	734	.735	.735	.735	.732	.73	.729
20	739	.739	.738	.737	.732	.733	.733
30	.747	.746	.741	.737	.732	.732	---
40	76	.755	.747	.736	.73	.728	.732
50	769	.767	.753	.738	.724	.719	.718
60	.778	.782	.756	.735	.713	.702	.694
70	.789	.782	.753	.721	.688	.669	.66

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.006	.01	.01	.009	.01	.01	.006
10	007	.01	.011	.01	.009	.01	.006
20	.008	.012	.013	.01	.008	.009	.008
30	.011	.014	.015	.011	.009	.01	---
40	015	.017	.017	.011	.009	.011	.011
50	.019	.022	.02	.013	.009	.011	.012
60	.023	.031	.024	.015	.009	.009	.012
70	.031	.033	.028	.018	.01	.01	.011

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.736	.738	.741	744	.741	.738	.736
10	.743	.744	.748	744	.741	.737	.734
20	753	.754	.752	746	.743	.737	.735
30	.77	.764	.759	.75	.742	.739	.741
40	.783	.78	.768	.754	.745	.741	---
50	.809	.797	.78	.757	.741	.736	.739
60	83	.828	.788	759	.733	.72	.72
70	.855	.835	795	.748	.711	.689	.679

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	006	.01	.013	.012	.013	.01	.006
10	.008	012	.015	.012	.012	.011	.006
20	.011	.015	.017	012	.012	.01	.008
30	018	.018	.021	.014	.011	.01	.008
40	.019	.022	.023	.015	.011	.011	---
50	029	.027	026	.017	.012	.013	.012
60	036	.046	.029	.02	.013	.012	.012
70	.043	.044	.036	.024	.015	.012	.013

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.745	.748	.751	.758	.751	.748	.745
10	.755	.756	.757	.757	.749	.743	.74
20	.77	.769	.781	.76	.75	.744	.741
30	.79	.787	.776	.767	.755	.748	.748
40	.818	.809	.792	.774	.762	.754	.756
50	.849	.835	.81	.782	.762	.758	---
60	.9	.871	.827	.79	.76	.752	.759
70	.966	.914	.848	.79	.745	.726	.724

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	.014	.016	.014	.016	.014	.008
10	.011	.016	.019	.014	.014	.012	.007
20	.015	.02	.029	.016	.014	.011	.007
30	.02	.024	.024	.017	.013	.011	.008
40	.028	.031	.027	.018	.015	.012	.012
50	.036	.037	.033	.021	.016	.014	---
60	.056	.045	.036	.025	.016	.015	.015
70	.075	.057	.046	.029	.019	.015	.016

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.756	.762	.764	.772	.764	.762	.756
10	.77	.772	.772	.772	.762	.755	.749
20	.791	79	.787	779	.763	.756	.75
30	.817	.813	.801	.789	.772	.761	.756
40	855	846	.821	.801	.779	.773	.768
50	.919	.89	.846	817	.788	.782	.788
60	.982	.941	.876	.832	.795	.788	---
70	1.127	1.009	.911	.844	.79	.774	.78

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.01	.019	.019	.018	.019	.019	01
10	.014	.02	.022	.019	.017	.014	.007
20	.021	.026	.027	.02	.017	.013	.007
30	028	.03	.029	.021	.017	.013	.008
40	038	.039	.033	023	.017	.012	.009
50	.061	.051	.036	.026	.019	.016	.013
60	.062	.057	.041	.029	.021	.016	---
70	.101	.063	047	034	.025	.019	.018

WHITE GYPSUM SAND — DRY

THETA ZERO = 0
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.727	.727	.724	.716	.722	.723	.723
20	.717	.718	.716	.709	.716	.716	.716
30	.713	.713	.712	.708	.71	.71	.707
40	.708	.707	.708	.702	.705	.703	.701
50	.702	.701	.7	.688	.695	.691	.688
60	.694	.693	.693	.69	.68	.674	.669
70	.677	.677	.678	.665	.642	.635	.626

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
10	.027	.028	.028	.025	.028	.026	.028
20	.027	.028	.029	.029	.028	.028	.027
30	.029	.029	.028	.03	.029	.029	.029
40	.03	.03	.03	.03	.03	.031	.03
50	.03	.031	.03	.03	.031	.031	.03
60	.033	.031	.034	.032	.034	.032	.033
70	.036	.037	.036	.036	.037	.036	.035

WHITE GYPSUM SAND — DRY

THETA ZERO = 10
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.717	.719	.721	.72	.721	.719	.717
10	.713	.716	.717	.718	.72	.721	---
20	.716	.714	.713	.714	.716	.716	.714
30	.71	.712	.712	.712	.711	.708	.704
40	.708	.71	.709	.707	.704	.7	.695
50	.705	.707	.704	.701	.693	.685	.677
60	.698	.699	.698	.691	.677	.664	.656
70	.684	.686	.684	.65	.639	.625	.614

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.028	.028	.028	.028	.028	.028	.028
10	.029	.029	.028	.027	.028	.028	---
20	.031	.03	.029	.029	.028	.028	.026
30	.032	.031	.031	.03	.028	.027	.027
40	.031	.033	.033	.03	.03	.028	.028
50	.037	.034	.033	.031	.029	.029	.028
60	.038	.038	.034	.034	.031	.03	.03
70	.042	.041	.039	.037	.035	.032	.031

WHITE GYPSUM SAND — DRY

THETA ZERO = 20
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.726	.728	.727	.729	.727	.728	.726
10	.726	.725	.725	.728	.727	.73	.729
20	.726	.725	.723	.726	.727	.729	---
30	.732	.726	.724	.727	.723	.722	.723
40	.73	.73	.729	.721	.718	.713	.71
50	.73	.729	.722	717	.705	.698	.693
60	.729	.726	.718	.71	.686	.674	.667
70	.719	.718	.708	.685	.649	.63	.62

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.028	.029	.028	.028	.028	.029	.028
10	.031	.03	.028	.027	.028	.028	.027
20	.032	.031	.03	.028	.027	.028	---
30	.037	.034	.031	.03	.028	.027	.027
40	.038	.036	.034	.029	.028	.026	.026
50	.041	.039	.034	.031	.029	.028	.027
60	.045	.041	.035	.032	.031	.028	.026
70	.05	.048	.04	.037	.033	.031	.029

WHITE GYPSUM SAND — DRY

THETA ZERO = 30
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.731	.733	.73	.734	.73	.733	.731
10	.733	.734	.731	.733	.732	.733	.73
20	.738	.739	.733	.732	.732	.734	.733
30	.743	.741	.736	.733	.731	.731	---
40	.753	.746	.739	.732	.726	.723	.727
50	.758	.754	.742	.73	.717	.71	.707
60	.762	.757	.742	.726	.702	.688	.681
70	.76	.755	.737	.701	.664	.644	.637

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.032	.03	.027	.025	.027	.03	.032
10	.033	.032	.028	.025	.027	.028	.028
20	.036	.034	.029	.026	.025	.026	.028
30	.04	.037	.031	.027	.027	.027	---
40	.046	.039	.033	.028	.026	.026	.025
50	.049	.045	.036	.03	.027	.026	.024
60	.053	.049	.037	.031	.029	.027	.024
70	.061	.054	.042	.034	.031	.027	.025

WHITE GYPSUM SAND — DRY

THETA ZERO = 40
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.735	.739	.741	.743	.741	.739	.735
10	.74	.741	.745	.742	.74	.738	.736
20	.747	.75	.747	.743	.741	.739	.734
30	.757	.76	.753	.747	.742	.738	.737
40	.771	.769	.759	.747	.738	.736	---
50	.788	.783	.766	.751	.731	.727	.727
60	.806	.797	.773	.751	.72	.707	.702
70	.816	.805	.773	.725	.689	.667	.656

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.033	.031	.025	.024	.025	.031	.033
10	.037	.034	.026	.024	.026	.029	.033
20	.041	.037	.027	.025	.024	.027	.028
30	.045	.041	.031	.025	.025	.027	.026
40	.05	.045	.032	.026	.025	.025	---
50	.059	.049	.036	.028	.026	.026	.023
60	.068	.057	.038	.029	.026	.025	.024
70	.075	.061	.043	.033	.029	.026	.023

WHITE GYPSUM SAND — DRY

THETA ZERO = 50
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.738	.738	.74	.746	.74	.738	.738
10	.744	.743	.743	.747	.741	.737	.736
20	.755	.751	.747	.748	.741	.736	.738
30	.769	.764	.756	.751	.745	.74	.744
40	.791	.781	.774	.758	.749	.748	.758
50	.817	.804	.78	.764	.755	.751	---
60	.847	.832	.795	.772	.751	.747	.756
70	.898	.868	.81	.771	.74	.725	.726

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.044	.041	.033	.026	.033	.041	.044
10	.046	.044	.036	.027	.032	.038	.041
20	.052	.049	.038	.028	.03	.038	.038
30	.056	.051	.04	.027	.028	.034	.034
40	.066	.055	.045	.028	.028	.031	.033
50	.074	.061	.042	.03	.026	.03	---
60	.078	.067	.045	.031	.028	.031	.029
70	.091	.075	.05	.033	.029	.028	.03

WHITE GYPSUM SAND — DRY

THETA ZERO = 60
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.747	.744	.748	.756	.748	.744	.747
10	.76	.754	.751	.756	.746	.741	.744
20	.776	.768	.762	.76	.749	.742	.744
30	.8	.788	.777	.766	.754	.747	.755
40	.834	.815	.792	.777	.762	.758	.766
50	.887	.852	.813	.792	.772	.771	.788
60	.95	.905	.843	.807	.78	.779	---
70	1.048	.97	.881	.82	.78	.774	.8

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.038	.037	.024	.016	.024	.037	.038
10	.045	.039	.025	.016	.021	.033	.037
20	.05	.044	.03	.015	.019	.029	.031
30	.055	.048	.033	.016	.019	.026	.028
40	.063	.051	.033	.019	.017	.021	.026
50	.085	.059	.035	.02	.015	.019	.021
60	.086	.065	.037	.021	.018	.02	---
70	.096	.069	.045	.024	.019	.019	.017

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.348	.349	.35	.348	.349	.349	.347
40	.334	.337	.337	.336	.335	.333	.33
60	.327	.328	.329	.327	.328	.326	.323
70	.319	.32	.321	.327	.323	.318	.314

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.007	.006	.007	.007	.008	.006	.006
40	.004	.005	.006	.006	.005	.004	.003
60	.012	.013	.013	.009	.005	.006	.006
70	.03	.03	.028	.012	.009	.012	.015

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.353	.351	.348	.341	.348	.351	.353
20	.38	.366	.352	.341	.338	.336	---
40	.384	.372	.354	.34	.331	.327	.325
60	.383	.375	.357	.342	.33	.322	.317
70	.384	.377	.356	.344	.327	.315	.308

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.009	.009	.007	.005	.007	.009	.009
20	.033	.027	.02	.009	.003	.004	---
40	.057	.046	.028	.015	.008	.009	.009
60	.066	.057	.036	.022	.016	.02	.024
70	.071	.061	.041	.027	.022	.024	.032

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.353	.352	.35	.351	.35	.352	.353
20	.381	.376	.362	.35	.344	.341	.34
40	.431	.408	.382	.361	.348	.34	---
60	.496	.453	.406	.375	.353	.341	.334
70	.552	.48	.417	.377	.352	.336	.327

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.022	.021	.019	.016	.019	.021	.022
20	.052	.046	.033	.018	.011	.007	.004
40	.121	.083	.047	.025	.012	.008	---
60	.192	.126	.063	.035	.019	.018	.019
70	.239	.144	.072	.042	.027	.021	.025

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 4000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.283	.337	.336	.338	.336	.337	.283
20	.313	.376	.354	.338	.33	.33	.27
40	.533	.432	.365	.355	.334	.326	.276
60	1.487	.467	.38	.357	.332	.322	---
70	2.166	.469	.381	.364	.327	.307	.269

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.028	.023	.019	.027	.019	.023	.028
20	.089	.062	.034	.028	.014	.006	.011
40	.434	.138	.046	.073	.028	.023	.018
60	.707	.144	.056	.06	.05	.048	---
70	.663	.12	.066	.065	.065	.063	.062

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.514	.51	.508	.509	.512	.508	.508
40	.479	.479	.48	.481	.481	.476	.475
60	.463	.464	.463	.46	.463	.457	.456
70	.446	.446	.446	.446	.444	.432	.431

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.006	.006	.007	.006	.005	.004	.004
40	.011	.01	.009	.007	.006	.008	.007
60	.035	.035	.035	.029	.029	.034	.033
70	.054	.055	.054	.037	.047	.053	.052

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.495	.49	.489	.488	.489	.49	.495
20	.509	.502	.492	.487	.484	.483	---
40	.52	.509	.5	.489	.482	.476	.472
60	.53	.522	.507	.491	.477	.466	.46
70	.538	.529	.509	.486	.468	.453	.444

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.009	.008	.008	.006	.008	.008	.009
20	.016	.015	.014	.005	.002	.005	---
40	.03	.025	.02	.011	.002	.005	.008
60	.044	.037	.027	.015	.009	.012	.017
70	.056	.046	.033	.018	.012	.016	.022

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.502	.503	.503	.492	.503	.503	.502
20	.528	.526	.515	.491	.498	.493	.494
40	.572	.558	.534	.494	.5	.493	---
60	.623	.598	.556	.504	.501	.553	.48
70	.664	.622	.566	.492	.494	.477	.466

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.014	.016	.014	.01	.014	.016	.014
20	.03	.03	.024	.013	.007	.007	.005
40	.062	.049	.031	.017	.008	.006	---
60	.094	.07	.042	.031	.015	.017	.013
70	.12	.084	.049	.039	.021	.019	.018

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 5000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.504	.504	.504	.499	.504	.504	.504
20	.56	.546	.521	.501	.491	.486	.484
40	.749	.612	.543	.51	.491	.481	.479
60	1.304	.675	.56	.522	.491	.473	---
70	1.86	.694	.568	.525	.486	.462	.45

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.021	.026	.025	.021	.025	.026	.021
20	.073	.065	.041	.02	.013	.01	.007
40	.262	.122	.049	.026	.018	.015	.012
60	.462	.147	.055	.038	.032	.033	---
70	.455	.138	.06	.047	.042	.046	.052

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.612	.612	.608	.603	.611	.609	.605
40	.569	.571	.573	.573	.572	.566	.562
60	.548	.549	.549	.546	.544	.538	.531
70	.523	.524	.525	.52	.513	.501	.489

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.002	.002	.003	.004	.005	.005	.003
40	.013	.013	.011	.009	.007	.012	.013
60	.046	.045	.043	.039	.041	.045	.049
70	.069	.067	.063	.057	.064	.07	.076

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.617	.617	.615	.604	.615	.617	.617
20	.782	.678	.613	.592	.582	.576	---
40	.648	.617	.59	.576	.567	.563	.56
60	.589	.582	.567	.558	.546	.537	.53
70	.56	.556	.543	.539	.517	.501	.488

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.005	.004	.004	---	.004	.004	.005
20	.05	.027	.011	.006	.004	.002	---
40	.035	.017	.012	.013	.015	.016	.016
60	.02	.03	.04	.037	.044	.048	.052
70	.047	.054	.063	.053	.066	.074	.078

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.604	.599	.594	.589	.594	.599	.604
20	.646	.626	.606	.59	.585	.582	.582
40	.709	.657	.62	.594	.58	.572	---
60	.779	.688	.629	.596	.573	.555	.547
70	.845	.706	.63	.59	.557	.533	.521

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.012	.011	.007	.007	.007	.011	.012
20	.041	.029	.019	.01	.005	.001	.001
40	.102	.056	.027	.015	.011	.011	---
60	.172	.084	.037	.026	.022	.027	.029
70	.218	.1	.044	.032	.032	.037	.041

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 6000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.602	.603	.601	.597	.601	.603	.602
20	.656	.643	.62	.599	.589	.585	.585
40	.977	.705	.636	.606	.586	.578	.578
60	2.252	.728	.644	.613	.581	.562	---
70	3.02	.721	.644	.612	.57	.54	.523

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.009	.013	.013	.014	.013	.013	.009
20	.049	.042	.026	.015	.006	.003	---
40	.32	.089	.033	.021	.014	.014	.016
60	.56	.088	.044	.035	.034	.038	---
70	.487	.077	.055	.045	.044	.056	.066

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.59	.585	.588	.576	.588	.583	.59
40	.557	.552	.555	.548	.555	.55	.552
60	.537	.532	.536	.527	.53	.524	.523
70	.511	.515	.514	.5	.509	.485	.484

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.009	.007	.008	.008	.008	.008	.01
40	.02	.021	.021	.02	.019	.019	.02
60	.05	.051	.051	.06	.052	.053	.053
70	.072	.066	.07	.082	.09	.08	.084

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.604	.615	.611	.609	.611	.615	.604
20	.793	.678	.612	.586	.575	.569	---
40	.631	.609	.582	.568	.561	.556	.553
60	.584	.578	.562	.547	.537	.529	.523
70	.561	.555	.54	.522	.506	.49	.482

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	.011	.012	.011	.012	.011	.008
20	.051	.03	.019	.011	.011	.012	---
40	.026	.018	.022	.02	.023	.024	.024
60	.024	.037	.047	.049	.052	.057	.058
70	.044	.055	.066	.067	.074	.084	.087

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.597	.597	.595	.591	.595	.597	.597
20	.659	.637	.608	.59	.582	.576	.575
40	.767	.672	.615	.586	.574	.566	---
60	.82	.677	.61	.579	.559	.544	.539
70	.841	.682	.603	.566	.54	.517	.507

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.008	.015	.016	.014	.016	.015	.008
20	.043	.036	.026	.017	.014	.014	.011
40	.149	.069	.034	.024	.023	.024	---
60	.211	.074	.045	.042	.043	.048	.05
70	.22	.08	.057	.056	.057	.063	.068

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 7000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.607	.604	.6	.593	.6	.604	.607
20	.656	.641	.616	.596	.591	.589	.588
40	.913	.697	.632	.601	.59	.583	.58
60	2.183	.727	.635	.594	.572	.56	---
70	3.051	.724	.623	.572	.539	.522	.519

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.01	.013	.018	.016	.018	.013	.01
20	.038	.036	.024	.018	.017	.015	.011
40	.27	.074	.035	.029	.03	.027	.024
60	.615	.08	.059	.059	.06	.058	---
70	.6	.082	.076	.081	.086	.085	.084

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.601	.605	.603	.663	.606	.601	.594
40	.569	.57	.568	.626	.567	.564	.562
60	.546	.547	.544	.607	.543	.539	.535
70	.509	.511	.507	.576	.501	.492	.486

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.008	.007	.007	.008	.006	.008	.009
40	.024	.022	.022	.021	.022	.023	.023
60	.06	.059	.059	.058	.058	.061	.061
70	.09	.089	.088	.087	.09	.093	.096

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.602	.604	.604	.601	.604	.604	.602
20	.666	.64	.61	.59	.58	.577	---
40	.634	.622	.595	.577	.568	.563	.563
60	.612	.6	.577	.56	.55	.541	.536
70	.594	.582	.558	.539	.524	.514	.506

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.005	.01	.012	.009	.012	.01	.005
20	.023	.02	.016	.011	.01	.009	---
40	.024	.023	.02	.019	.019	.021	.021
60	.007	.022	.034	.039	.042	.043	.044
70	.013	.034	.049	.063	.059	.06	.063

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.6	.599	.6	.598	.6	.599	.6
20	.683	.641	.613	.597	.589	.587	.586
40	1.123	.678	.619	.596	.587	.581	---
60	.803	.649	.608	.581	.566	.555	.551
70	.735	.626	.584	.551	.529	.511	.501

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.006	.011	.013	.012	.013	.011	.006
20	.047	.028	.019	.014	.014	.011	.01
40	.337	.054	.028	.027	.025	.026	---
60	.17	.041	.055	.058	.059	.061	.063
70	.097	.058	.08	.083	.086	.091	.095

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 8000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.608	.607	.606	.604	.606	.607	.608
20	.647	.639	.622	.607	.601	.596	.594
40	.931	.688	.641	.615	.601	.591	.589
60	4.959	.708	.643	.604	.58	.564	---
70	5.186	.692	.623	.57	.532	.513	.517

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.007	.012	.014	.013	.014	.012	.007
20	.019	.023	.02	.015	.015	.012	.011
40	.269	.044	.028	.03	.029	.028	.026
60	.797	.058	.059	.064	.069	.066	---
70	.728	.073	.084	.092	.101	.101	.096

WHITE GYPSUM SAND — WET

THETA ZERO = 0
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.61	.603	.593	.584	.596	.605	.602
40	.565	.566	.564	.566	.569	.566	.563
60	.538	.538	.537	.541	.541	.535	.53
70	.508	.511	.511	.517	.513	.499	.49

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	---	---	---	---	---	---	---
20	.036	.037	.037	.035	.037	.037	.037
40	.022	.025	.027	.028	.029	.028	.024
60	.008	.006	.002	.009	.007	.004	.008
70	.029	.025	.019	.012	.011	.021	.03

WHITE GYPSUM SAND — WET

THETA ZERO = 20
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.587	.586	.583	.582	.583	.586	.587
20	.603	.594	.586	.579	.577	.574	---
40	.611	.601	.586	.577	.569	.562	.559
60	.61	.601	.583	.569	.552	.538	.53
70	.609	.599	.575	.553	.528	.508	.499

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.041	.039	.037	.036	.037	.039	.041
20	.049	.043	.038	.036	.035	.034	---
40	.059	.052	.043	.035	.031	.03	.026
60	.065	.058	.044	.032	.024	.019	.015
70	.072	.063	.044	.031	.023	.016	.01

WHITE GYPSUM SAND — WET

THETA ZERO = 40
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.589	.585	.584	.585	.584	.585	.589
20	.65	.629	.595	.583	.575	.573	.574
40	.871	.666	.599	.582	.572	.567	---
60	.815	.645	.59	.568	.549	.535	.528
70	.581	.632	.569	.54	.505	.486	.476

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.045	.043	.037	.031	.037	.043	.045
20	.082	.065	.039	.03	.032	.034	.033
40	.26	.1	.035	.02	.02	.019	---
60	.252	.073	.022	.014	.013	.013	.014
70	.063	.065	.028	.038	.037	.036	.037

WHITE GYPSUM SAND — WET

THETA ZERO = 60
WAVELENGTH = 9000

DIRECTIONAL REFLECTANCE

	PHI						
THETA	0	30	60	90	120	150	180
0	.597	.592	.588	.589	.588	.592	.597
20	.642	.625	.604	.591	.58	.577	.581
40	.869	.688	.621	.596	.581	.574	.577
60	2.237	.725	.626	.594	.563	.546	---
70	3.536	.724	.616	.57	.521	.499	.495

DEGREE OF POLARIZATION

	PHI						
THETA	0	30	60	90	120	150	180
0	.049	.046	.036	.028	.036	.046	.049
20	.079	.062	.038	.027	.03	.034	.037
40	.283	.106	.032	.017	.016	.019	.018
60	.656	.11	.024	.017	.015	.013	---
70	.693	.093	.032	.035	.036	.034	.034

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